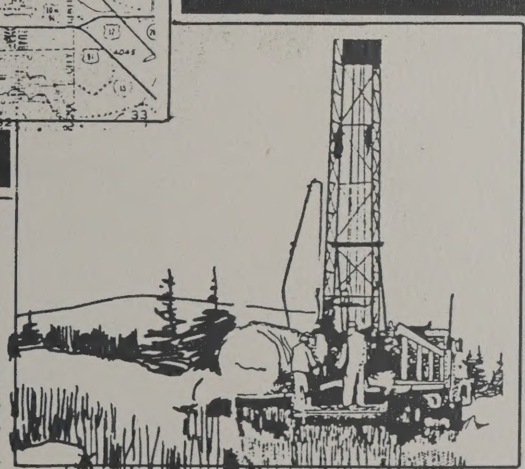
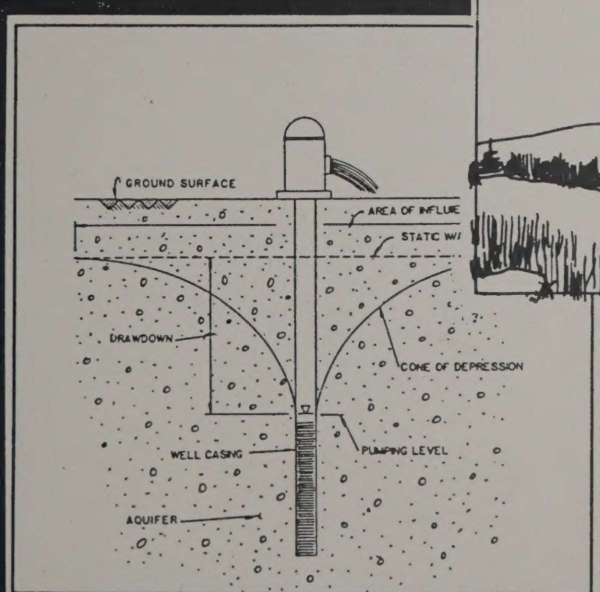
Assessment of Availability of Groundwater For Municipal Water Supply - Helena, Montana





HYDROMETRICS

ASSESSMENT OF AVAILABILITY OF GROUNDWATER FOR MUNICIPAL WATER SUPPLY HELENA, MONTANA

for

City of Helena
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Helena, Montana 59601
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by

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June 1983

ASSESSMENT OF AVAILABILITY OF GROUNDWATER FOR MUNICIPAL SUPPLY - HELENA, MONTANA

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ASSESSMENT OF AVAILABILITY OF GROUNDWATER
FOR MUNICIPAL SUPPLY - HELENA, MONTANA

Increased demand for municipal water in the City of Helena requires continued development of additional water supplies. A water treatment plant is proposed for Ten Mile Creek to supply up to 15 MGD (millions gallons per day) of water to the Helena water system. Both construction and operation of this treatment plant will be expensive and all potential alternatives must be considered to insure the community will have sufficient water at the least cost. The City of Helena, under an agreement with the Montana Department of Health and Environmental Sciences, needs to upgrade the Ten Mile water system by July, 1987 to eliminate turbidity problems. Development of a groundwater supply is a possible alternative to the proposed treatment plant. Other significant municipal water developments in progress are an expansion of the Missouri River Treatment Plant and installation of additional water transmission and distribution lines. Development of additional water supplies must integrate with and compliment the existing water system and constructed improvements to the system.

Groundwater is widely used in the Helena Valley and in the Ten Mile Creek drainage. Hundreds of wells in the area supply water for domestic and stock use and there are numerous high capacity wells in use for irrigation and public water supplies. Groundwater is present essentially everywhere within and peripheral to the Helena Valley and in the Ten Mile drainage. Groundwater is abundant in many areas and there are many wells that furnish 500 gpm (gallons per minute) or more.

Although the Helena community water system uses some groundwater, the potential for development of additional groundwater to supplement the city supply, or the use of groundwater as an alternative to the Ten Mile water treatment plant, has not received a detailed technical evaluation.

This groundwater investigation is in response to a request from the City of Helena for a comprehensive evaluation of the area's groundwater resources as a potential source for supplementing the community supply.

Basic questions that need to be answered are:

1) Is groundwater available in sufficient quantity and quality to supplement the existing water supply system or to substitute for the proposed Ten Mile water treatment plant at 9 MGD or 15 MGD?

2) Is the cost of development, including capital and maintenance costs, competitive with improvement of existing surface water supplies?

3) What potential problems could occur as a result of development of large quantities of groundwater for municipal use?

SCOPE

A comprehensive program for a systematic investigation of groundwater as a potential source of municipal water for the community of Helena was developed by Hydrometrics. This comprehensive program included three major phases which are:

Phase I	Groundwater Supply Potential and Connection to the Community Water Supply
Phase II	Site Selection, Test Drilling and Pumping Tests
Phase III	Preliminary Design of Production Wells and Detailed Economic Analysis

The City of Helena requested a specific proposal for a portion of the Phase I work. This proposal was prepared by Hydrometrics, submitted and funded. The scope of this portion of the Phase I work includes:

1) Assembly and Review of Hydrogeological Data
2) Data Evaluation and Delineation of Areas Suitable for High Capacity Wells
3) Preliminary Evaluation of Groundwater Development Constraints
4) Phase I Report

Specific components of this study include a detailed well inventory, interviews with Helena valley residents, evaluation of existing hydrogeologic data for the Helena Valley, testing of selected wells and delineation of areas potentially suitable for high capacity wells. Hydrometrics has worked with the Groundwater Feasibility Study

Committee in the assessment of groundwater sources and formulation of groundwater development options. Input from the study committee has been valuable in this investigation.

All abbreviations used in this report are described when first used and are also listed in Appendix A. A description of the method used to indicate location of wells is in Appendix B.

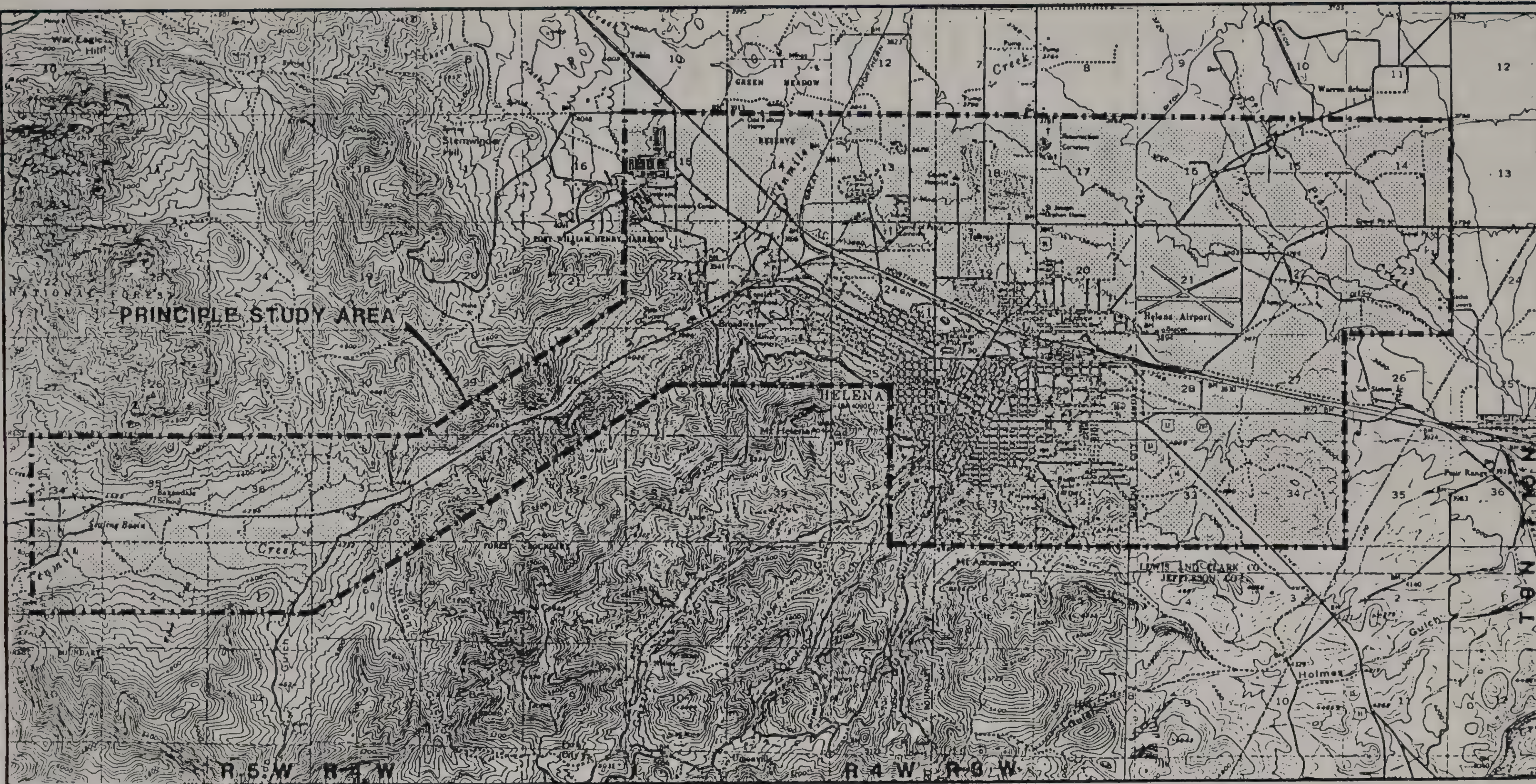
STUDY AREA

Extent and Description

The study area examined in this investigation is shown on Figure 1 and on Plate I (in report pocket). Study area boundaries were determined based on proximity to existing water system transmission lines. Study area boundaries extend about one mile beyond the existing city water mains. This distance has been extended to the east and along Prickly Pear Creek downstream of the water treatment plant because of the presence of high capacity producing wells in that area. The study area encompasses a total of about 34 square miles. The Ten Mile valley has been included because any groundwater development in this area could utilize the gravity supply lines running from the Ten Mile settling basin to the west side of Helena.

The Helena Valley is a broad intermontaine basin situated approximately 10 miles east of the continental divide in west-central Montana. Ten Mile, Seven Mile and Prickly Pear Creeks are major tributaries to the southwestern portion of the valley. Valley elevations range from

about 4000 feet where Ten Mile Creek enters the valley to 3650 feet at Lake Helena. The City of Helena is located on the southern flank of the basin at the mouth of Last Chance Gulch. Considerable urban development has occurred north of the city on valley fill deposits of the Helena Valley. The Ten Mile Creek drainage is long and relatively narrow and extends west from the Helena Valley (Figure 1 and Plate 1).



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HELENA, MONTANA AND
EAST HELENA, MONTANA

SCALE

5000 0 5000 10000 feet

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FIGURE 1

LOCATION OF PRINCIPLE STUDY AREA

Prepared By HYDROMETRICS Helena, Mt.

REVIEW OF HYDROGEOLOGIC INFORMATION

PREVIOUS REPORTS

The geology and groundwater hydrology of the Helena area has been described in numerous previous reports. The Helena Valley basin is bounded on the north, west and east by sedimentary rocks of the Precambrian Belt Super Group. Paleozoic and Mesozoic rocks are exposed on the valley boundary to the south in the vicinity of the City of Helena and in the lower portions of the Ten Mile Creek Valley. Late Cretaceous or early Tertiary igneous rocks associated with the Boulder Batholith are exposed along the southern valley boundaries, in the Ten Mile Creek drainage west of Helena and in the Scratch Gravel Hills northwest of Helena. Detailed descriptions of Helena area geology are found in Knopf (1913, 1963), Pardee and Schrader (1933), Lorenz and Swenson (1951), Schmidt (1977), and Stickney and Bingler (1981).

Unconsolidated valley fill deposits in the Helena Valley have been the primary focus of previous groundwater studies. Studies of groundwater resources in the Helena Valley include Lorenz and Swenson (1951), Layne Minnesota Co. (1971), Botz (1971), Wilke and Coffin (1973), Montgomery Engineering (1977), Morrison-Maierle-Montgomery (1978), Moreland and others (1979) and Moreland and Leonard (1980).

Wells and lithologic data in the Helena Valley deeper than 500 feet are rare, however, Knopf (1913) reported that drilling to as deep as 1200 feet did not reach below valley fill deposits. Valley fill deposits of

Tertiary and Quaternary age have been described by Lorenz and Swenson (1951). The Tertiary deposits are referred to as "lake beds" and consist of gray and tan clays and silts with occasional sand and gravel layers. These "lake bed" deposits outcrop at various locations near the valley boundaries but are commonly buried by 50 to 150 feet of younger silt, sand and gravel deposits in the Helena Valley within the study area. Water yields from wells in the Tertiary "lake bed" sediments are generally modest with ten to thirty gallons per minute being common. Late Tertiary gravels of possible Pliocene Age locally overlie the finer grained "lake bed" sediments.

Most wells in the Helena Valley withdraw water from sands and gravels of Quaternary age. Quaternary deposits consist of a complex mixture of layers and lenses of clay, silt, sand and gravel deposited by tributary drainages including Ten Mile, Seven Mile, Last Chance Gulch and Prickly Pear Creeks. These sediments have been deposited over the generally finer grained Tertiary materials.

Alluvial fan and alluvial floodplain deposits of these stream systems cover much of the study area and probably have a maximum thickness of about 150 feet. Examination of well logs, geophysical logs and results of a Layne-Minnesota Co. (1971) resistivity survey indicate existence of significant fine grained silty and clayey material, but not as a continuous extensive layer. The deposits and environment of the Quaternary valley fill alluvium has resulted in a heterogeneous mixture of silty to sandy gravel textured channel, bar and overbank deposits.

Variations in lithology occur rapidly and frequently in both the vertical and horizontal directions.

Channel and bar deposits consisting of sand and sandy gravel materials appear to provide the highest yields of water to wells. Existing geologic information is not sufficiently detailed to allow prediction of locations of these buried features.

Previous evaluations of the potential for development of groundwater sources for a municipal supply have indicated that areas suitable for the construction of high capacity wells (500 to 1500 gpm) exist in the Helena area but that test well drilling would be required as part of system design (Botz, 1971; Layne-Minnesota Co., 1971; Morrison-Maierle-Montgomery, 1978). These previous reports have evaluated existing geologic data but have not examined constraints or economic costs and benefits of a groundwater system.

AGENCY FILES

To identify large capacity wells within the study area, files of several governmental organizations were examined. Montana Department of Natural Resources and Conservation (DNRC) files were reviewed. These files include notice of appropriation and notice of completion forms for wells drilled or filed on since 1962, a comprehensive computer listing of groundwater appropriations claimed under the requirements of Senate Bill 76 and a computer listing of permits and certificates issued since July 1, 1973. Montana Bureau of Mines and

Geology (MBMG) also maintains a file of well logs and groundwater appropriation forms. A computer listing of the Montana Bureau of Mines and Geology (MBMG) records was reviewed and well logs for high capacity wells within the study area obtained from their files. Lewis and Clark County water rights records were examined to cross check DNRC and MBMG files and to identify additional well owners. Well logs and groundwater appropriation files obtained from these sources were the starting point of the comprehensive well inventory. Files of the former Montana Department of Health and Environmental Sciences, Subdivision Bureau were reviewed to obtain information on wells and well tests submitted for approval of water supply systems for subdivisions.

Records of the City of Helena relative to the city water system available from the water department and the city clerk were examined. Information on the Ten Mile Creek water system, the Eureka and Bedrock supply and the Woolston well was obtained from city records. Montana Historical Society records on the Helena Consolidated Water Company, the Helena Water Works Company and mining in the Helena area were reviewed in an attempt to find evidence of groundwater occurrences of possible interest for municipal development. Helena area newspapers from the period 1866 to 1890 (Helena Radiator, Helena Herald and Montana Mining Review) were examined to see if articles on mining activity in the Helena area would provide any useful information on groundwater occurrences especially in the bedrock areas to the south and on the west side of the city.

ORGANIZATIONS AND INDIVIDUALS

Numerous organizations and a large number of individuals were contacted as part of this evaluation of groundwater resources in the Helena area. Contacts included interviews with former City of Helena water department employees, local residents with expertise in water resources, a local well driller and individual owners, tenants and managers of irrigation systems and high capacity wells. Information on many of the contacts came from the City Water Department, the Groundwater Feasibility Study Committee and interested city residents. A large number of contacts were made as part of the inventory of wells. Many people provided useful information about the local groundwater system and often recommended talking to other people. A comprehensive list of study contacts is in Appendix C.

EVALUATION OF GROUNDWATER POTENTIAL

WELL INVENTORY

A detailed inventory of high capacity wells within the study area was conducted. High capacity wells were arbitrarily determined to be those with reported yields greater than 100 gpm. Several wells with yields somewhat less than 100 gpm are included in the final inventory; these wells are generally of interest because of their location, the geologic information they supply or the reported yields were higher than 100 gpm. A total of about 60 wells or springs with reported or measured yields greater than 100 gpm are identified in or adjacent to the study area (Plate 1).

The well inventory involved interviews with well owners and, where possible, field checking of well locations, well completion data and yields. Well locations listed are in Table 1 by Township, Range, Section and location within each Section. A description of the methodology for describing well locations is in Appendix B. In many cases field checking and interviews with current owners greatly modified the information obtained from DNRC and MBMG files which is obtained from water well drillers and well owners. Previous well inventories, particularly those of Lorenz and Swenson (1957) and Botz (1971) provided information important to establishing the current status of specific wells. A tabulation of pertinent data for each of the wells identified on Plate 1 is shown in Table 1. A clear distinction is made between information reported in DNRC and MBMG files

TABLE 1. WELL INVENTORY - HIGH CAPACITY WELLS
HELENA GROUNDWATER STUDY AREA

Location	Well Depth (ft)	Yield (gpm) Reported	Yield (gpm) Field Measured	Static Water Level (ft)	Pumping Water Level (ft)	Owner	Use	Well Log Available	Pump Test Data	Remarks
9N5W3CB	52	300	-	-	-	City of Helena	M	-	-	10 HP pump
10N3W8BC	120	1400	-	18	-	Valley Development	M	-	-	
10N3W8BC	160	1100	-	18	-	Valley Development	M	-	-	Former irrigation well
10N3W8BC	60	280	-	-	-	Valley Development	U	-	-	
10N3W11DC	110	1100	-	32	-	A. Herrin	U	-	-	Former irrigation well
10N3W11DC	~40	~500	-	-	-	A. Herrin	U	-	-	
10N3W11BA	68	1250	-	18	-	E. Donaldson	D	-	-	
10N3W11DA	127	180	-	-	-	J. Johnson	M	Y	-	Leisure Village
10N3W11DA	108	180	-	-	-	J. Johnson	M	Y	-	Leisure Village
10N3W11DB	237	500 - 1000	-	-	-	J. Johnson	M	Y	-	Need log or some record
10N3W14ACD	60	250	-	32	-	W. Cottrill	I	Y	-	Cottrill claims well pumps 250 gpm
10N3W14ADD	102	98	-	30	60	H. Staler	I,S	Y	-	
10N3W14ACD	73	92	-	25	73	A. Patterson	I,D,S	Y	-	
10N3W14BBD	80	90	100(est)	12	32	C. Smithers	I,D	Y	-	
10N3W14DBD	95	600	-	26	85	A. Hermanson	I	Y	-	
10N3W14DDD	109	600	300	34	54	City of East Helena	M	Y	Y	Layne Well #1
10N3W15ACD	52	1040	-	-	38	J. Oitzinger	I	Y	-	Former owner - Rogan
10N3W15BDA	100	500	-	Flowing	-	B. Lichtwardt	D,I	-	-	Flowing 5 gpm
10N3W15BAA	39	90	-	5	25	D. Munson	U	Y	-	Former irrigation well
10N3W15DBC	30+	1300	-	7	-	D. Burnham	I	-	-	Pit reportedly never pumps down
10N3W15DDD	95	600	600	13	33	City of Helena	U	I	Y	Test well observation well within 200 feet
10N3W17BCC	134	500	-	23	90	Resurrection Cem.	I	Y	-	
10N3W17BAA1	105	235	-	24	38	T. Allen	M	Y	Y	Supplies Beaverhead Subdivision
10N3W17BAA2	107	235	-	12	38	T. Allen	M	Y	Y	Supplies Beaverhead Subdivision
10N3W18ABB	75	225	200(est)	15	-	H. Cranmer	I,S	-	-	
10N3W18ADD	112	300	-	~35	172	D. Anders	M	Y	-	

TABLE 1, Continued

Location	Well Depth (ft)	Yield (gpm) Reported	Yield (gpm) Field Measured	Static Water Level (ft)	Pumping Water Level (ft)	Owner	Use	Well Log Available	Pump Test Data	Remarks
10N3W18ADD	108	100	-	~35	80	D. Anders	-	-	-	
10N3W18ACB	~70	950	-	-	-	R. King	I	-	-	Former owner - Yuhas
10N3W18BD	74	300	-	~21	-	E. Yuhas	D	-	-	2 Wells 30" from each other
10N3W18BD	98	>1000	-	~21	-	E. Yuhas	I	-	-	
10N3W19ACC	320	90	-	30	-	E. McHugh	M	Y	-	
10N3W19ACB	140	65	-	28	-	E. McHugh	M	-	-	
10N3W19BAD	9	600	-	-	-	E. McHugh	M	-	-	Well dug in alluvium
10N3W19BCD	100	350	-	-	-	City of Helena	I	-	-	Drilled in 1952, Golf Course
10N3W19CAB	308	165	-	25	-	City of Helena	I	Y	-	Drilled in 1977, Golf Course
10N3W19CAD	30	300	-	1	-	City of Helena	I	Y	-	Infiltration gallery installed 1982, 36" casing, Golf Course
10N4W13CAA	90	380	-	3	26	M. Greely	I,S	Y	-	
10N4W13CCC	18	330	~500	5	7	City of Helena	I	-	Y	Woolston Well, 30 ft. diameter
10N4W13DAD1	70	400	-	1	-	J. Anderson	I	Y	-	
10N4W13DAD2	100	450	-	-	-	J. Anderson	I	Y	-	
10N4W14BCB	195	100	-	3	-	G. Hiltabrand	I	-	-	
10N4W14CCB	10	450	-	5	-	M. Sennett	S	-	-	Open pit - developed spring
10N4W14DDC1	48	125	-	-	-	B. Carlson	I,D	-	Y	
10N4W14DDC2	60	150	-	-	-	B. Carlson	I	-	Y	
10N4W15ABC	34	110	-	-	-	F. Schatz	I,S	Y	Y	
10N4W15BAB	150	100	100	15	16	Veterans Admin.	U	Y	Y	VA Water System Report, 1977
10N4W22CD & 10N4W27BB	40 to 178	900 (combined)	-	-	-	State Nursery Co.	I	-	-	6 wells in use
10N4W22ACA	168	90	-	-	-	F. Schatz	I,S	-	-	
10N4W22DAD	22	355	-	12	-	Tri-County D&D	I,S	-	-	Unused May 1983
10N4W23AAD	25	450	450	~5	~7	Burlington Northern/ Green Meadow CC	I	Y	-	Golf Course irrigation, 32 ft. diameter
10N4W23ADB1	110	150	-	-	-	L. Reynolds	M	Y	-	
10N4W23ADB2	44	140	-	-	-	L. Reynolds	M	Y	-	

TABLE 1. Continued

Location	Well Depth (ft)	Yield (gpm) Reported	Yield (gpm) Field Measured	Static Water Level (ft)	Pumping Water Level (ft)	Owner	Use	Well Log Available	Pump Test Data	Remarks
10N4W23BAB	14	100	-	-	-	L. Schneider	U	-	-	Former owner - G. Blank
10N4W23BBB	60	100	-	-	-	D. Armstrong	U	-	-	
10N4W23BBD1	17	500	-	-	-	X-L Industries	IN	-	-	Brickyard, unused
10N4W23BBB2	8	250	-	-	-	G. Buswell	I,S	-	-	
10N4W23BDB	71	90	-	-	-	Mont. State Fish, Wildlife & Parks	U	Y	-	Former owner - Reber Realty
10N4W24ABB	26	500	100	3	9	Home of Peace Cemetery	I	Y	Y	2 dug wells, 10 feet apart
10N4W28AAC	52	100	-	8	-	F. Gannon	I,S,D	Y	-	
10N4W28ACD	228	600	-	0	90	F. Gruber	H	Y	-	Water temp. = 150°F
10N4W28CCB	20	150	-	4	-	C. Smallwood	I,S	-	-	Apparently no longer used
10N4W28CCC1	70	80	-	-	-	N. Alm	I,S	-	-	
10N4W28CCC2	280	100	-	25	-	N. Alm	I,S	Y	-	
10N4W31ADD	32	400	-	-	-	A. Grunenfelder	I	-	-	
10N4W31CCB	30	200	-	-	-	R. Isaak	I,S	-	-	
10N4W36ADB	47	500	-	-	-	City of Helena	M	-	-	Eureka Well
10N4W36DBB	47	550	-	20	-	D. Hurni	I,S,D	-	-	Part of old "Bedrock" water system
10N5W34DD	60	200	-	50	-	City of Helena	M	-	-	Dug well, 25 HP pump

Code for Use

I = Irrigation
S = Stock
D = Domestic
H = Heating
IN = Industrial
M = Municipal
U = Unused

1) Well depths and water levels are approximate depth below ground surface.

2) Water level depths reported from well logs, owners or measured.

3) Well diameters generally 4 to 12 inches except for dug wells.

or by the well owner and information measured in the field as part of this study or published in earlier professional reports.

The distribution of high capacity wells within the study area (Plate 1) indicates that there are several areas with noticeable concentrations of high yield wells. There are several high capacity wells in the large area of the Ten Mile Creek alluvial flood plain extending from the Kessler Brewery-Country Club area to the confluence of Ten Mile and Seven Mile Creeks north of the county fairgrounds. Portions of this area also have a very shallow water table, are essentially undeveloped and contain few wells. Groundwater sources in this area include springs, constructed drain systems or open pits that are used primarily for irrigation and stock water supplies. The largest number of high capacity wells are in the northeastern portion of the study area in the general vicinity of the water treatment plant.

Interviews with well owners and tenants typically included requests for information on high capacity wells including well location, depth to water, well yield, type of pump, drawdown characteristics, well use, geologic data and knowledge of other wells in the area. Well sites were visited where feasible and well locations plotted on 1:10,000 scale aerial photographs. Well locations were transferred from the photos to a 1:24,000 scale base map for inclusion in this report (Plate 1). Information gathered from interviews, field reconnaissance and previous investigations was reviewed and compiled to produce Table 1. There are, no doubt, additional wells with high yields or useful

geologic information within the study area, but the information obtained from the compiled inventory is adequate for the study purposes.

WELL TESTING

Selected wells were tested as part of this study to provide reliable data on well yields, water level drawdowns and aquifer characteristics. Single well drawdown and recovery tests of short duration were conducted on five wells. With owner cooperation, testing consisted of pumping the wells with existing pumps and simultaneously measuring water level drawdowns. Discharge was measured utilizing bucket and stopwatch, free discharge from pipes or a small flume. Water levels were recorded with a calibrated electric probe. Results of the tests are in Table 2.

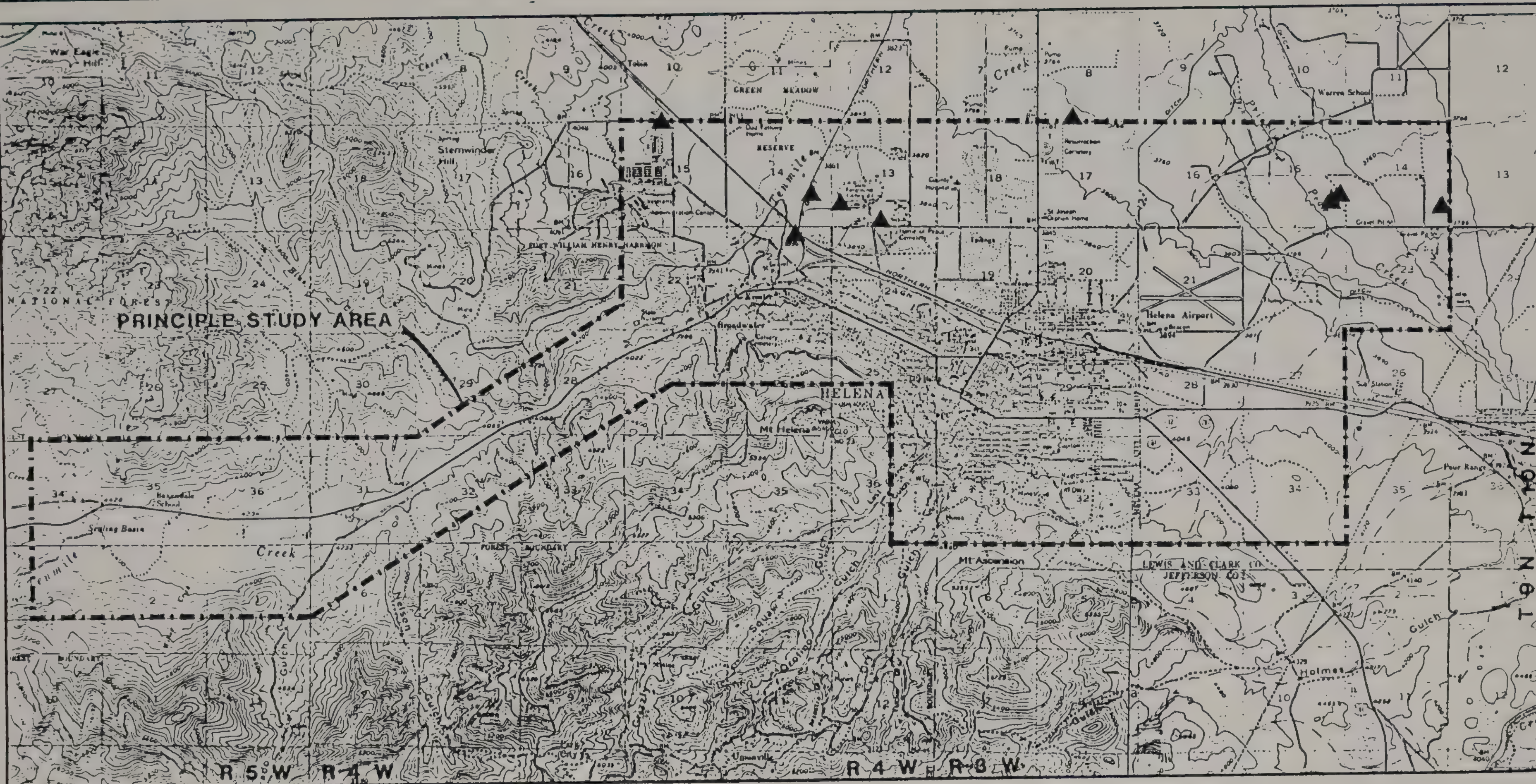
Review of existing reports and discussions with various agencies and organizations has provided information on several other pumping well tests in the study area. Results of these tests are also summarized in Table 2. Locations of wells for which test data is available are shown on Figure 2.

HYDROGEOLOGICAL INTERPRETATIONS

Review of existing hydrologic and geologic reports, well logs and evaluation of the location and characteristics of existing high capacity wells, springs and areas of shallow groundwater results in a number of generalizations about hydrogeologic conditions in the study

TABLE 2. SUMMARY OF AQUIFER TEST DATA FOR THE HELENA VALLEY AREA

Owner/ Location	Test Date	Test Operator	Test Type	Observation Well	Distance of OBS Well from Pumping Well (ft)	Discharge Rate (gpm)	Test Duration (min)	Maximum Drawdown (ft)	Estimated Transmissivity (T) (gpd/ft)	Remarks
City of East Helena - Well # 1 10N 03W 14DDD	5/12/83	Hydrometrics	Const. Disch.			250 to 300 (?)	100	19.56	15,000 - 90,000	Very poor well efficiency. T. estimated from specific capacity.
City of Helena 10N 03W 15DDD	2/23/78	Morrison-Maierle	Const. Disch.			600	1440	33.65	257,000	T estimated from recovery data. Data indicates poor well efficiency.
				OBS # 1	3	-	1440	?		
				OBS # 2	213	-	1440	0	-	
Thomas Allen 10N 3W 17BAA		Tangen Engineering							44,175	
City of Helena 10N 04W 13CCC	5/13/83	Hydrometrics	Const. Disch.			500	100	2.23	?	Well about 30 feet in diameter.
B. Carlson Irrigation Well 10N 04W 14DDC	5/16/83	Hydrometrics	Const. Disch.	-	-	60	90	3.54	158,000	
				Domestic Well	24	-	90	1.18	158,000	
Veterans' Administration 10N 04W 15BAB	5/77 (?)	Montgomery Engineers	Const. Disch.	-	-	100	240	1.2	145,000	
Burlington-Northern 10N 04W 23AAD	5/5/83	Hydrometrics	Const. Disch.	-	-	450	100	1.28	150,000	Well about 32 feet in diameter.
Home of Peace Cemetery 10N 04W 24ABB	5/6/83	Hydrometrics	Const. Disch.	-	-	100	60	9.42	15,000 to 60,000	T estimated from specific capacity (s.c. = 10.6) and well efficiencies of 25% and 100%.



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SCALE

5000 0 5000 10000 feet

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▲ WELLS WITH TEST DATA AVAILABLE

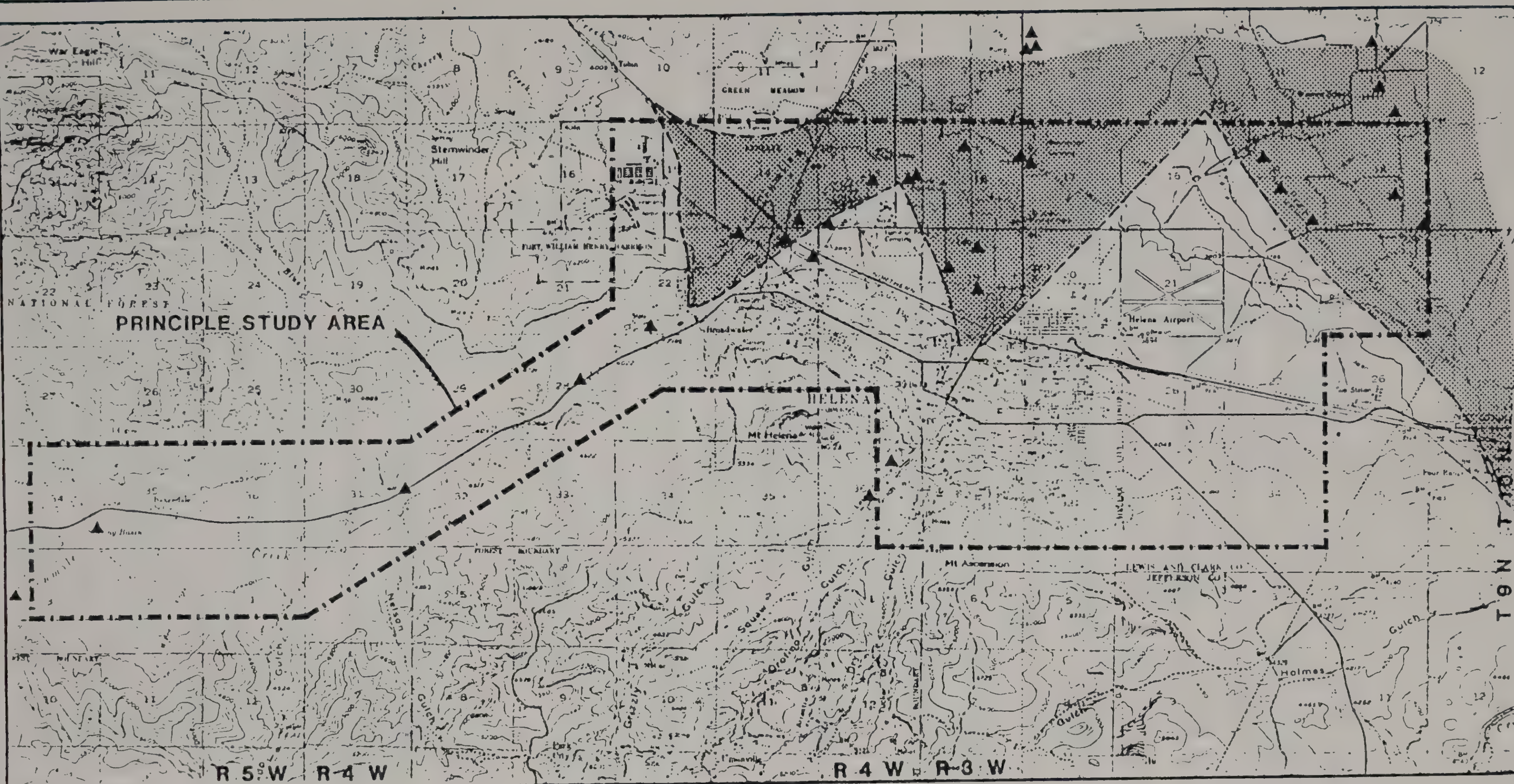
FIGURE 2

LOCATION OF WELLS FOR WHICH TEST DATA IS AVAILABLE

Prepared By HYDROMETRICS Helena, MT

area. Regions of interest for development of groundwater supplies in the study area can be separated into several geological situations. Groundwater supplies in the Helena area are obtained from Quaternary channel, fan and flood plain deposits; Quaternary alluvial deposits along tributary stream courses; Tertiary "lake bed" and valley fill deposits; and fractured bedrock aquifers. The alluvial fan and flood plain deposits along Ten Mile Creek, Last Chance Gulch and Prickly Pear Creek have differences with respect to potential for groundwater development. Two other geologically distinct areas for possible consideration for groundwater development are the Ten Mile Creek drainage west of Helena particularly where it broadens above Colorado Gulch and bedrock and tributary drainages in and south of the city.

High capacity wells have been developed in Quaternary alluvial deposits along Ten Mile Creek and Last Chance Gulch and in alluvial fan and flood plain deposits. Wells with yields greater than about 100 gpm are shown on Plate 1 and wells with yields greater than 300 gpm are on Figure 3. The shaded areas in Figure 3 indicate areas considered to have potential for development of high capacity wells possibly suitable for use in Helena's municipal supply system. Areas outlined on Figure 3 generally correspond to the Quaternary channel and floodplain deposits of Ten Mile Creek, Last Chance Gulch and Prickly Pear Creek. The majority of these wells are less than 100 feet deep and most are completed in sandy gravel.



SOURCE OF BASE: U.S.G.S. 1:62,500,
HELENA, MONTANA AND
EAST HELENA, MONTANA

LEGEND

AREA WITH POTENTIAL FOR DEVELOPING HIGH CAPACITY WELLS

▲ EXIST. WELLS WITH REPORTED YIELD GREATER THEN 300 GPM

FIGURE 3

DELINEATION OF AREAS WITH POTENTIAL FOR DEVELOPING HIGH CAPACITY WELLS

Prepared By HYDROMETRICS Helena, Mt.

A number of wells penetrate Tertiary "lake bed" sediments and occasional layers of sand and gravel are reported on well logs to be present in these "lake beds". In some areas of the valley, most commonly at low elevations near Lake Helena, flowing artesian wells have been completed in the Tertiary sediments. Yields from the Tertiary are generally small to moderate but several wells drilled into Tertiary sediments have reported yields of greater than 100 gpm. These include five wells within the principle study area with depths greater than 100 feet and the Masonic Home well (11N03W21CD) which is 460 feet deep and is reported to flow at 125 gpm (Lorenz and Swenson 1951). Another well reportedly completed in "lake bed" sediments drilled to a depth of 510 feet at the Green Meadow Country Club has a yield of only 25 gpm (Lorenz and Swenson, 1951). Available information on Tertiary sediments indicates that although these predominantly fine grained materials can yield appreciable quantities of water there is insufficient data to consider them a promising source of municipal water.

Alluvium in the Ten Mile Creek valley upstream from where it enters the Helena Valley yields significant quantities of water to a number of wells (Plate 1 and Table 1). Below the confluence of Colorado Gulch and Ten Mile Creek the valley is generally very narrow. Ten Mile Creek is reported to gain substantial flow in this stream section (A. Smith, personal communication). Several high capacity wells exist indicating that high permeability alluvium exists along this narrow section of the Ten Mile Valley. The limited valley width makes this area a

questionable prospect for development of any significant portion of Helena's municipal supply. Above Colorado Gulch the Ten Mile Valley drainage bottom broadens to as much as a mile. Field examination and available drill hole data indicate alluvium is thin, probably less than 40 or 50 feet, and contains some highly permeable zones. There are very few wells in this area and the only high capacity well in this upper portion of the Ten Mile Creek Valley is the City of Helena well near the settling basin (09N05W03CB). Ten Mile Creek alluvium appears to consist of sand, gravel and boulders derived primarily from granitic rocks. The relatively thin alluvium in the upper portion of the Ten Mile Valley probably has an insufficient storage volume or recharge to sustain a 9 to 15 MGD municipal supply. Recharge from Ten Mile Creek is probably greatest in the spring and least in the late summer and fall when demand is greatest. An accurate assessment of the upper Ten Mile Valley alluvium for a conventional groundwater supply system is constrained by the lack of hydrogeological data.

Bedrock areas and shallow tributary stream alluvium within and adjacent to in the city and immediately to the south along the Orofino, Grizzly and Dry Gulch drainages is used for a number of domestic water supplies and contributes water to the City of Helena's Hale system. Several reports of large quantities of water in the limestone and granitic rocks to the south of Helena can be traced to the early mining days when water was pumped from mine workings. Placer mine tailings in Orofino, Grizzly and Dry Gulches were converted into interceptor systems by the Helena Water Works Company and its predecessors. The

Dry Gulch system was apparently damaged in the 1935 earthquake and has not been used since. Water from Orofino and Grizzly Gulches has supplied water to the City of Helena for nearly 100 years. Some of the water supplied to the Eureka well reportedly comes from a flooded mine shaft. Information on the origin of all water to the Hale-Eureka system is difficult to interpret, however most of the water supply is apparently derived from Orofino and Grizzly Gulch alluvium. The existing Hale system supplies between one and two MGD (Morrison-Maierle-Montgomery, 1978) which is similar to the volume reported in earlier studies (Main, 1903; Wright, 1948). The Dry Gulch collection system was reported to supply about 50 gpm (Main, 1903). Although the existing collection system probably loses some water back to Last Chance Gulch alluvium and the city storm water system, there is little information available to evaluate the potential for obtaining significant quantities of additional water from these drainages.

DELINEATION OF GROUNDWATER AREAS

Review and evaluation of all available hydrogeological data suggests subdivision of the principle study area into five smaller groundwater areas:

1) West Valley between Fort Harrison and Green Meadow Drive,
2) Central Valley in the vicinity of Montana Avenue and the old dredge tailings to Interstate I-15,
3) East Valley extending from Interstate I-15 to the eastern edge of the principle study area,

4) Bedrock and tributary drainages south of Helena,

5) Ten Mile Creek drainage.

Each of these areas has individual geological characteristics; are affected by different stream drainages; and have different groundwater development potentials.

GROUNDWATER SYSTEM

A discussion of the occurrence and movement of water in aquifers within and adjacent to the Helena Valley is important in understanding the groundwater system and evaluating potential development options. Aquifer characteristics and groundwater recharge, movement, storage and discharge are important components in the hydrological system. A glossary of geological and hydrological terms used in this report are contained in Appendix D.

DELINEATION OF AQUIFERS

Aquifers or water yielding zones within the study area include:

1) Quaternary alluvium deposited by streams flowing into the Helena Valley,
2) Quaternary fan and floodplain deposits that blanket most of the valley,
3) Tertiary "lake bed" deposits underlying essentially all of the valley and
4) Fractured bedrock of various ages and lithologies in the mountains and foothills peripheral to the Helena and Ten Mile Creek Valleys.

In all aquifers, groundwater is stored in and transmitted through the interconnected pore spaces. These pore spaces consist of openings between particles created when a rock or geologic formation was formed,

termed primary porosity, and openings created by forces acting on rocks after they were formed (secondary porosity). Large pore spaces that occur in materials such as sand or gravel generally results in greater ability to store, release and transmit water than secondary porosity such as that occurring as fractures or joints in rocks such as granite or shale. Typically, fractures and joints in hard rocks result in a porosity of a few percent whereas porosity in granular materials such as sand and gravels range from about 15 to 30 percent. This means granular materials can store much more water per unit volume than fractured rocks. Most of the water available for withdrawal in high capacity wells in the Helena area is stored in and transmitted through unconsolidated sediments with relatively high primary porosity.

Geological characteristics of aquifer materials affects groundwater contained in the saturated void space. Water in an underground reservoir can be under artesian (confined) or water-table (unconfined) conditions. Water in an artesian aquifer is overlain by a relatively impermeable material and is under sufficient pressure to rise above the aquifer when penetrated by a well. An artesian well flows when the pressure is sufficient to raise water in the well above the ground surface. The water surface of water-table aquifers is exposed to atmospheric pressure and the top of the saturated zone is known as the water table. Shallow alluvial aquifers in the Helena, Ten Mile and smaller adjacent valleys are commonly under water table conditions. Deeper alluvial materials beneath confining clay layers and the Tertiary "lake bed" materials are often under confined or semi-confined

conditions. Few of the artesian wells in the southwest portion of the Helena Valley have sufficient pressure to flow at the ground surface.

HYDROLOGIC CYCLE

Groundwater is part of the hydrologic cycle which is the natural system through which water passes. Commencing as atmospheric water vapor, water passes into liquid (rain) and solid form (snow, hail), thence along the ground surface as streamflow or into the ground as groundwater, then returning to the atmosphere as vapor by means of evaporation and transpiration. The hydrologic cycle is illustrated in Figure 4. Factors of importance to groundwater in the hydrologic cycle are recharge, discharge, movement and storage.

GROUNDWATER RECHARGE AND DISCHARGE

Only a small percentage of the total precipitation percolates downward beneath plant roots to recharge the groundwater system. Recharge to the alluvial and valley fill in the Helena Valley aquifers comes from direct precipitation (rain and snow) and infiltration of irrigation and streamflow. Ten Mile and Prickly Pear Creeks and other smaller streams are a significant source of area recharge to the Helena Valley groundwater system. In the eastern portion of the study area and in areas of the valley north and east of Helena a considerable amount of irrigation occurs. Approximately 20,000 acres are irrigated with water from the Missouri River supplied by the Helena Valley Irrigation District (Ron Schofield, May 1983, pers. comm.). Irrigation also occurs with waters from Ten Mile and Prickly Pear Creeks. Significant

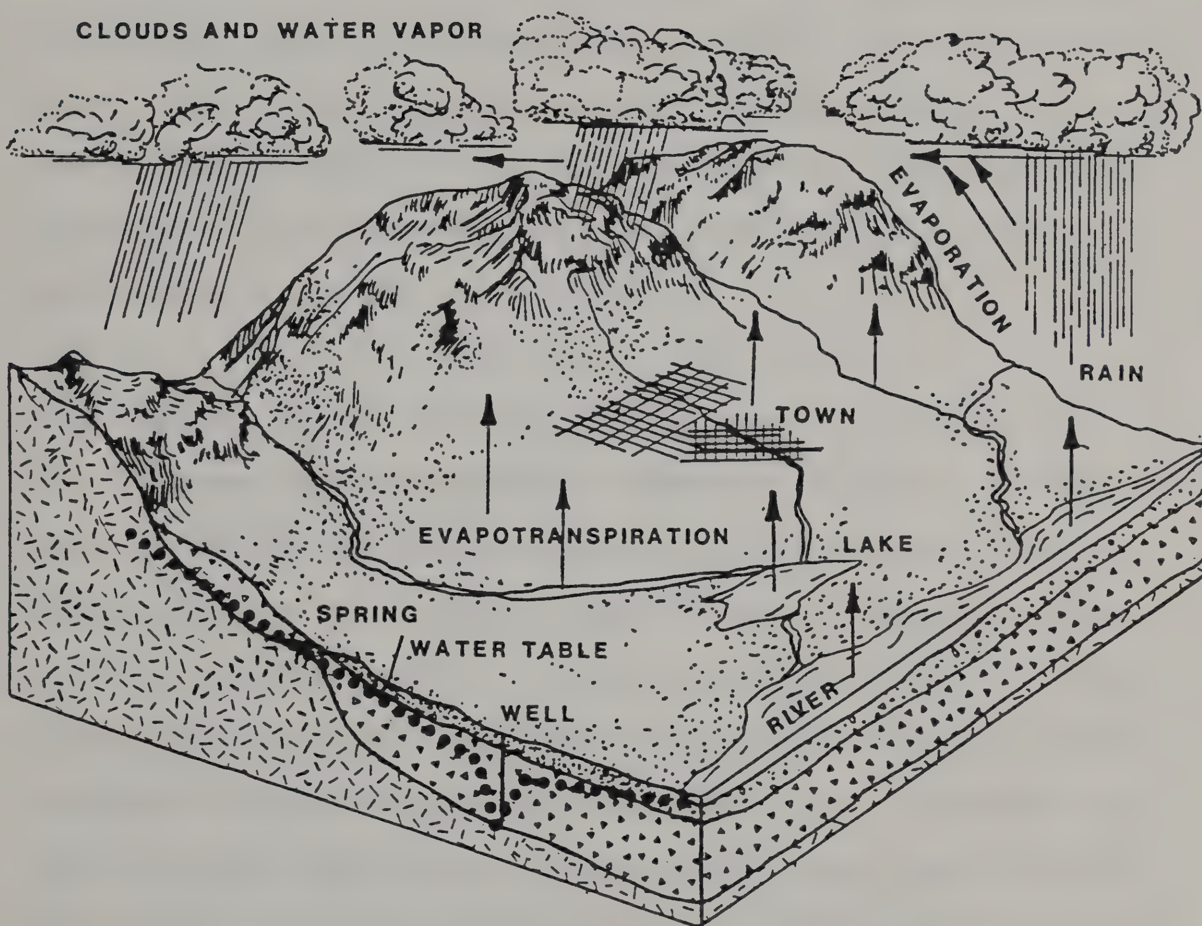


FIGURE 4: SCHEMATIC DIAGRAM OF LOCAL HYDROLOGIC CYCLE

rises in the groundwater table in shallow aquifers during the irrigation season shows irrigation is a major source of recharge in the Helena Valley. Previous studies including Lorenz and Swenson (1951) have emphasized the importance of irrigation to recharge in the Helena Valley. Morrison-Maierle-Montogmery (1978) estimated the average annual recharge from the Helena Valley Irrigation District to be greater than 50,000 acre-feet from 1972 to 1975. This recharge is equivalent to about 108 MGD over a five month irrigation season or approximately 75,000 gpm.

In the western portion of the study area near Fort Harrison a large local irrigator uses approximately 7 MGD over a five month irrigation season (A. Smith, May 1983, pers. comm.). Assuming an efficiency of 50% the recharge to groundwater would be about 2400 gpm. Another smaller but not insignificant source of groundwater recharge is losses from the municipal water system. Morrison-Maierle-Montogmery (1978) estimated a system leakage of 0.8 MGD or about 578 gpm. Examination of records in their report shows an estimated 1980 summer water useage of about 13.4 MGD, an estimated leakage of 13% and, 25% water unaccounted for, some of which may be lost in "excessive leakage". Total water loss from the water system during the peak water use months could be several times the estimated 578 gpm leakage.

Bedrock peripheral to the valley contains fractures and joints and is recharged by rainfall and snowmelt. As a result, the bedrock contains groundwater which generally is moving toward valleys and stream

drainages. Insufficient information exists to quantify recharge from bedrock. Based on water levels in wells and a report by Montgomery Engineering (1977), groundwater gradients indicating discharge to the valley exist on the south and west sides of the valley within and adjacent to the study area.

Discharge from the groundwater reservoir occurs as inflow to streams, springs and seeps, transpiration by plants and discharges from wells and drains. Water table maps developed by Lorenz and Swenson (1951), Montgomery Engineering (1977) and water level data reported by Moreland and Leonard (1980) show groundwater flow in the study area is generally northeasterly toward Lake Helena. Figure 5 is an approximate water table map of shallow alluvium in the Helena area. Configuration of the water table contours are after Lorenz and Swenson (1951) and Moreland and Leonard (1980). Seasonal fluctuation of streamflows in the Ten Mile and Prickly Pear Creeks result in some segments of the stream seasonally receiving water from the groundwater system and other segments providing recharge to groundwater.

Discharge from wells locally lowers the water level under water-table conditions. The water level decline takes the form of an inverted cone of dewatered material. This area of dewatering is called the drawdown cone (Figure 6). The pumped well is at the center of the cone of depression and the shape and dimensions of the cone are determined by aquifer characteristics and the rate and duration of pumping from the well.

LEGEND

3950 APPROX. ELEV. OF SURFACE OF SHALLOW GROUNDWATER TABLE

APPROX. LIMIT OF SATURATED ALLUVIAL DEPOSITS

GENERAL DIRECTION OF GROUNDWATER FLOW

SOURCE OF BASE: U.S.G.S. 1:62500 HELENA AND EAST HELENA, MONTANA

FIGURE 5: WATER TABLE CONTOUR MAP OF SOUTHWESTERN HELENA VALLEY

HYDROMETRICS Helena, Mt.

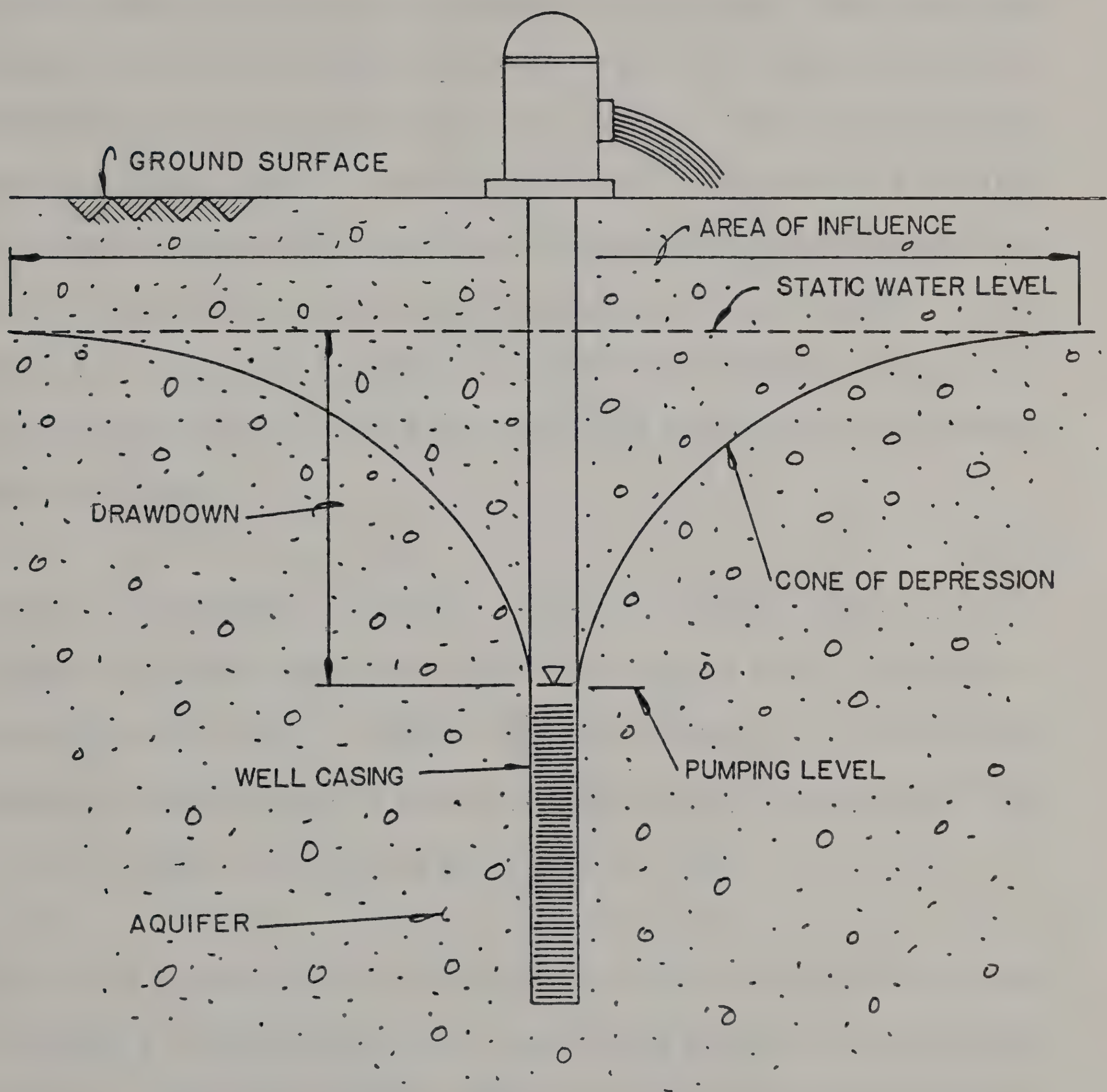


FIGURE 6

SCHEMATIC REPRESENTATION OF PUMPED WELL SHOWING DRAWDOWN, CONE OF DEPRESSION AND AREA OF INFLUENCE

GROUNDWATER MOVEMENT

Groundwater movement is controlled by the permeability of the aquifer and the gradient or slope of the groundwater surface. Areas with high permeability and gradient have high rates of groundwater flow. Conversely gentle groundwater gradients and less permeable materials result in small rates of groundwater flow. The slope of the water table and the direction of groundwater movement can be determined from the water-table contour map for the shallow alluvial aquifer of the Helena Valley (Figure 5). The direction of groundwater movement is downslope perpendicular to the water table contours and is shown by arrows on Figure 5.

The rate of groundwater movement is very slow compared with the rate of movement of surface water. The velocity of surface water in streams is commonly on the order of several feet per second while the rates of movement of groundwater are commonly on the order of a few feet or tens of feet per year to as high as a few feet per day.

The rate of groundwater flow through an aquifer is dependent on the permeability of the material, the water table gradient and the aquifer thickness. The rate of flow under prevailing conditions across an aquifer of unit width of one foot, with a water table gradient of one foot per foot is known as the transmissivity. Transmissivity is very useful in estimating the potential yield of wells drilled into an aquifer and the flow of groundwater in an aquifer. Transmissivity

commonly is determined from data obtained from well pumping tests. Higher values of transmissivity indicate increased ability to supply water to wells. Values of transmissivity for the Helena Valley are available from several aquifer tests listed in Table 2; additional test data is reported by Moreland and others (1979).

GROUNDWATER STORAGE

Aquifers can store large quantities of water in pore spaces. For example an unconsolidated sandy gravel material can store as much as 80,000 gallons per acre per foot of depth and a fractured rock 8,000 gallons per acre per foot of thickness. Groundwater recharge increases the water in storage and water levels rise. As recharge decreases and becomes less than discharge then water is removed from storage and water levels decline. Aquifers, therefore, act as underground reservoirs and seasonally store and release water.

The amount of groundwater that can be stored and released in each cubic foot of aquifer as water levels rise and fall one foot is termed the coefficient of storage or storativity. This important aquifer property can be determined from well pumping tests and, for unconfined materials, can be estimated from the relative abundance of clay, silt, sand and gravel in the aquifer.

Water levels in the Helena Valley normally rise in the late spring and summer in response to groundwater recharge from runoff and irrigation.

Water levels decline in the fall and are lowest in winter and early spring.

Water level fluctuations in the Helena Valley have been measured by Moreland and others (1979), by Moreland and Leonard (1980) and Lorenz and Swenson (1951). Generally, water levels near the valley center and along Ten Mile Creek show the least fluctuation and water levels in wells in the higher elevation, coarser alluvial fans show the greatest seasonal fluctuations. For example, the area east of the Helena Airport shows seasonal water level fluctuations of up to 25 feet, whereas water levels lower in the valley and north of the airport show only a few feet of annual fluctuations (Lorenz and Swenson, 1951).

DEVELOPMENT CONSTRAINTS

Groundwater for a municipal water supply must meet a number of criteria and constraints including:

1) It must be available in sufficient quantity for long-term use;
2) Chemical, physical and bacteriological quality must be suitable for public use;
3) The rights of prior groundwater and surface water appropriators must not be adversely affected;
4) Capital, operating and maintenance costs must be acceptable.

GROUNDWATER AVAILABILITY

Availability of groundwater for municipal use has been a major consideration in this study. Based on analysis of recharge and storage there is sufficient groundwater in the Helena Valley and the Ten Mile Creek drainage to supply the projected long-term municipal needs. A criteria used for evaluation of groundwater potential is that each production well must supply a minimum of 500 gpm. Individual wells yielding less than 500 gpm would require excessive construction, piping, control and maintenance costs. Groundwater availability is discussed in detail in the Development Options section of this report.

GROUNDWATER QUALITY

Quality of groundwater is another consideration in development of a

municipal supply. Water quality of groundwater within and adjacent to the principle study area has been studied by several previous investigators (Lorenz and Swenson, 1951; Botz, 1971; Wilke and Coffin, 1973; Moreland and others, 1979; Moreland and Leonard, 1980). Considerable water quality data for the Helena area is also available from the Montana Department of Health and Environmental Sciences. These previous studies have shown, that with few exceptions, groundwater in the Helena Valley is of good to excellent quality and is acceptable for public supply. Groundwater in the Helena Valley tends to be a moderately hard to a very hard calcium-bicarbonate type with concentrations of total dissolved constituents of less than 500 milligrams per liter. With very few exceptions, waters from the valley meets all Federal primary and secondary drinking water standards (40 CFR Parts 141, 143). Groundwater quality in the Ten Mile Creek valley and in tributary drainages south of Helena is generally slightly better quality than most water in the valley. Substitution of groundwater for the existing Ten Mile Creek system would cause a small increase in the content of dissolved minerals and increased hardness in the Helena water supply. Water quality would be similar to that presently obtained from the Hale and Eureka systems. Turbidity, taste and odor problems associated with the current Ten Mile system would be eliminated.

Moreland and Leonard (1980) identified areas of shallow groundwater in the valley and obtained samples from a few wells in several areas that had above normal specific electrical conductivity and nitrate

concentrations suggesting influence from human activities such as irrigation and waste disposal. Shallow wells typically showed more problems than deeper wells.

Movement of bacteria in groundwater flowing through granular aquifer materials is limited. Many years of public health experience with water wells and sanitary waste disposal systems such as septic tanks and drainfields has shown a separation of 50 to 100 feet prevents bacteriological pollution. All potential well locations in the Helena Valley or in the Ten Mile Creek drainage would have a considerable horizontal separation from sources of bacteriological pollution and no biological problems would be anticipated. Although there are some wells influenced by septic tank drain fields, municipal waste disposal systems and irrigation, groundwater of suitable quality for municipal supply can be obtained from all the potential groundwater development areas considered in this study.

IMPACTS ON EXISTING USERS

A concern in developing a municipal groundwater supply system is potential adverse impacts to existing groundwater and surface water appropriators. Long-term and continuous withdrawal of groundwater from shallow alluvium will result in some local lowering of the water table. This potentially could affect nearby wells and downgradient groundwater and surface water resources. Development of a municipal groundwater supply for the City of Helena would require acquisition of water right permits under Montana's 1973 Water Use Act. Montana water law provides

protection for existing groundwater appropriators but does not prohibit changes in the conditions of water occurrence such as "lowering of the water table, artesian pressure or water level if the prior appropriator can reasonably exercise his water right under the changed conditions" (MCA Sec. 85-2-401). In practice, requirements of the water rights acquisition process will limit development of groundwater resources to areas and aquifers where it can be demonstrated that significant adverse impacts will not occur to existing water appropriators.

In order to avoid significant drawdowns from a well or group of wells developed for a municipal supply, sufficient distance must be maintained between new and existing wells in the same aquifer. The nature and extent of impacts on existing water users would depend on the location and design of the municipal groundwater supply system. Drawdown impacts are a function of the geometry of the cone of depression created by the supply wells and their distance from existing wells. Two of the potential development areas considered in this study have relatively high concentrations of existing groundwater users. The Central Valley area, primarily underlain by alluvial deposits of Last Chance Gulch, and the East valley area where Prickly Pear Creek alluvium is the principle aquifer, are both areas of considerable existing groundwater development. Although the potential for development of large volume groundwater supplies certainly exists in both of these areas, it must be recognized that the potential for conflicts with existing users are highest in those areas where moderate to high density groundwater development has already occurred.

Streamflows may also potentially be affected by groundwater use. As indicated in the previous discussion of recharge and discharge, removal of groundwater from an aquifer requires either an increase in recharge or a decrease in discharge at some other point. Development of a well or well field near a stream will induce some recharge from the stream to the underlying alluvium. This situation is often used to advantage in the development of groundwater supplies and commonly aquifer recharge occurs from streams during periods of high flows when there is little conflict with other water users.

CONNECTION TO EXISTING WATER SYSTEM

An important component of the capital and operational costs of a groundwater supply system is the piping and pumping system required to tie into Helena's present system. Helena's existing supply and distribution system is described in the water system master plan (Morrison-Maierle-Montgomery, 1978). Replacement of the Ten Mile supply would require supplying water to the Malben-Woolston system. This distribution system supplies water to most of the city south of Custer Avenue. The Malben-Woolston system, also known as the high pressure zone, obtains water from both the Ten Mile and Missouri River systems. Ten Mile Creek water supplies the Woolston Reservoirs via three gravity supply lines originating at the Ten Mile settling basin about seven miles west of Helena. Water pressure is maintained by the water elevation in the Woolston Reservoirs which are cross-connected with the Malben Reservoir. Maximum water level elevation in the

Malben-Woolston Reservoir system is about 4320 feet above mean sea level.

An alternate supply to the Ten Mile system should be designed to furnish water to the Woolston Reservoir or to mains supplied by the Malben-Woolston system at a pressure similar to that furnished by the present system. An efficient, well designed supply system would minimize the length of new supply line to be constructed, minimize the energy requirements to pressurize the system and be compatible with the current operation and future anticipated growth of the system. Utilization of the existing Ten Mile supply lines or connection into lines supplied by the Ten Mile system on the west end of the city would require minimum changes to the existing distribution system. Two of the potential development areas investigated, the Ten Mile Creek drainage and the bedrock and tributary drainages south of Helena, would have the significant advantage of low pumping head to the Woolston or Malben Reservoirs.

GROUNDWATER DEVELOPMENT AND SUPPLY COSTS

The cost of groundwater supplied to the community must compare favorably with the cost of a surface water supply - specifically the proposed Ten Mile Creek treatment plant. The cost of a groundwater system includes capital costs for construction and pumping of test wells, construction of production wells, piping to the water transmission system, pumps, pump houses, valves, controls and other appurtenances. Operational costs include power, maintenance and

periodic rehabilitation or replacement of wells and pumps. Wells can be installed sequentially as demand increases so some capital costs can be deferred.

The scope of this study does not include a detailed cost analysis or cost comparisons with existing and planned water supply sources. A preliminary estimate of groundwater development costs is included in the Development Options section of this report. Water development cost is a major consideration and detailed cost comparisons will be required to clearly establish the best alternative for the additional water supply.

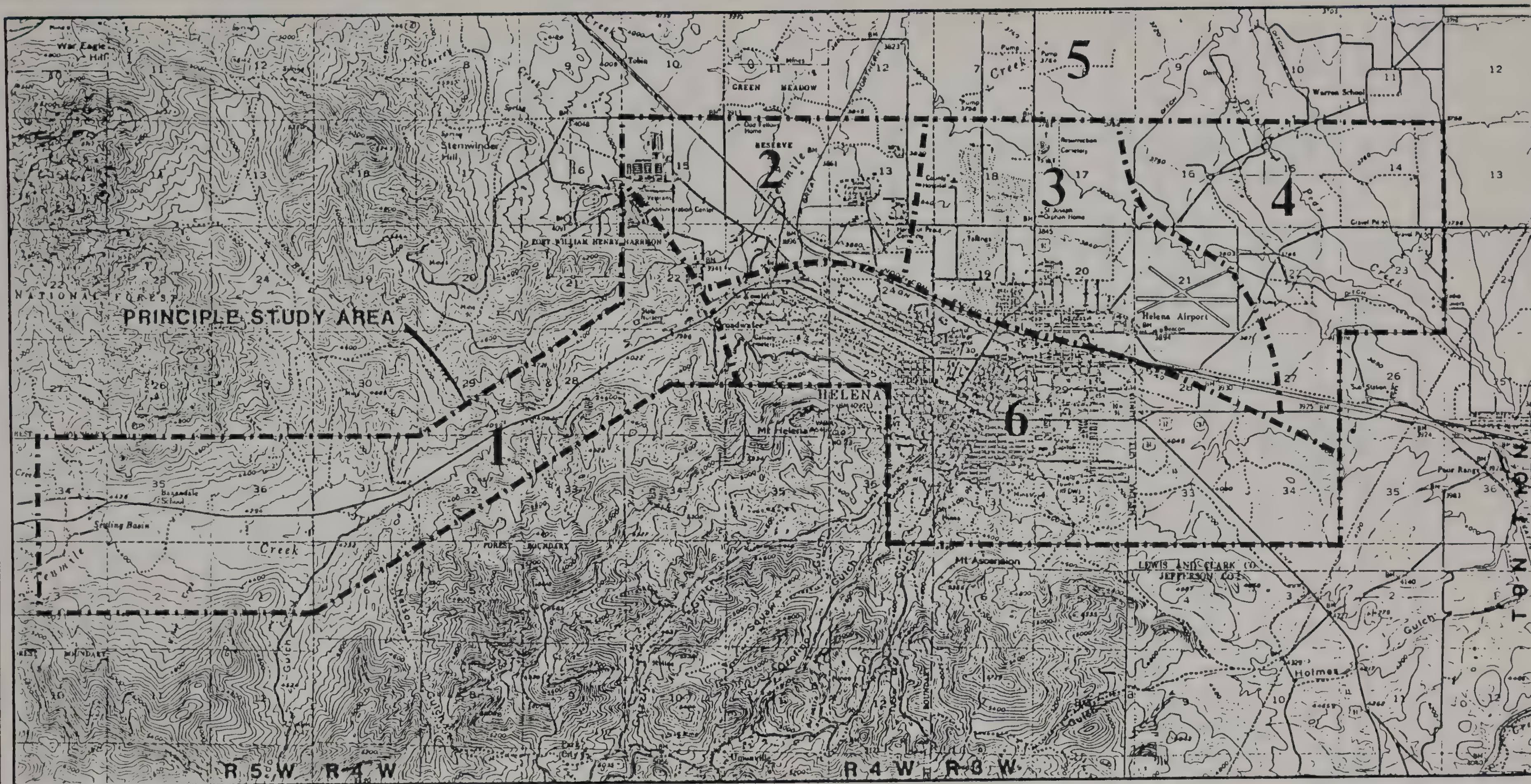
DEVELOPMENT OPTIONS

Development of groundwater to supply 9 to 15 MGD (6200 to 10,400 gpm) will require one or possibly several well fields. Each well field will consist of a few wells connected to a common pipeline and electrical line. The number of wells in the field and locations of the fields is a function of hydrological considerations and constraints described in this report. If each well produces a minimum of 500 gpm or a maximum of 1500 gpm, a total of 5 to 21 wells will be needed. If high capacity collector wells can be used then fewer wells will be required to meet the water supply requirements.

Five separate groundwater development areas within the principle study area are delineated for purposes of this report (Figure 7). These are West Valley, Central Valley, East Valley, Bedrock and Tributaries south of Helena and Ten Mile Creek Valley. In addition to these areas the North Valley, outside of the principle study area, is considered because of the large number of high capacity wells existing to the north of the study area boundary.

WEST VALLEY

The West Valley area geologically consists of Ten Mile and Seven Mile Creek channel and floodplain deposits (Figures 3 and 7). There is considerable shallow groundwater and there are numerous springs, ponds, active and abandoned stream channels and groundwater drain systems in this area. Ten Mile Creek loses considerable groundwater in this area by infiltration and from irrigation withdrawals. During the summer



SOURCE OF BASE: U.S.G.S. 1:62,500,
HELENA, MONTANA AND
EAST HELENA, MONTANA

1 - TENMILE CREEK
2 - WEST VALLEY
3 - CENTER VALLEY
4 - EAST VALLEY
5 - NORTH VALLEY
6 - BEDROCK AND TRIBUTARIES

N

FIGURE 7

AREAS OF POTENTIAL GROUNDWATER DEVELOPMENT

Prepared By, HYDROMETRICS Helena, Mt.

flow period Ten Mile Creek essentially goes dry due to infiltration into the subsurface as it crosses this area (A. Smith, May 1983, 1983, pers. comm.). There are a few high capacity wells in this area (Plate 1) with yields as high as 500 gallons per minute. Due to the shallow water table, much of the area is undeveloped and there is limited existing groundwater use. Well logs and geophysical information indicates the depth of unconsolidated alluvium material in the area is relatively shallow and is underlain by Tertiary "lake bed" sediments or older bedrock material at depths generally ranging from 40 to 100 feet. It is reported that bedrock becomes shallow toward the north edge of this area near the Scratch Gravel Hills (T. Lindsay, May 1983, pers. comm.). The Green Meadow Country Club and the Woolston wells have produced 450 and 330 gpm, respectively, for many years. These wells are large diameter (about 30 feet) and shallow and presently are used for irrigation. The West Valley area receives considerable recharge from infiltration from Ten Mile and Seven Mile Creeks and from extensive irrigation. Bedrock peripheral to this area also appears to be contributing recharge to the alluvium (Montgomery Engineering, 1977). The major constraints to groundwater development in this area are the shallow depth of alluvial materials and the high pumping head required to put water into the Woolston-Malben water system.

All high capacity wells in this area are shallow and remove water from unconsolidated alluvium along Ten Mile Creek. The limited thickness of unconsolidated alluvium constrains the volume of groundwater in storage. There are no hydrogeological data for large portions of the

West Valley area. Based on the limited hydrogeological information it appears that a collector type well may be the best groundwater development option for this area. A groundwater collector well consists of a large diameter central well and a series of horizontal wells radiating out from the main collector well. This type of installation is widely used in development of shallow groundwaters, particularly in the vicinity of active streams. This type of installation has the advantage of being able to develop large flows by collecting shallow groundwater from a large area. A groundwater collector well would require a pumphouse, chlorinator and connection to city water transmission lines. The nearest water transmission lines are the lines extending down Ten Mile Creek to the City of Helena and the line to the Woolston well near the fairgrounds (Figure 8).

CENTRAL VALLEY

The Central Valley area extends from approximately Green Meadow Drive to Highway I-15 and includes the old dredge tailings and the Helena Airport areas. Geologically this area consists of outwash deposits from Last Chance Gulch and from other smaller drainages south of Helena. These alluvial fan deposits consist of a mixture of clay, silt, sand, gravel and boulders. In the airport area alluvial materials are finer grained and consist of interlayered silt, clay, sand and gravel. Depth of these deposits is variable extending from a few tens of feet near the mouth of Last Chance Gulch to over 100 feet toward the north. There is considerable urban development in much of this area and many wells used for household and stock purposes are present. There are a few high capacity wells in this area that yield

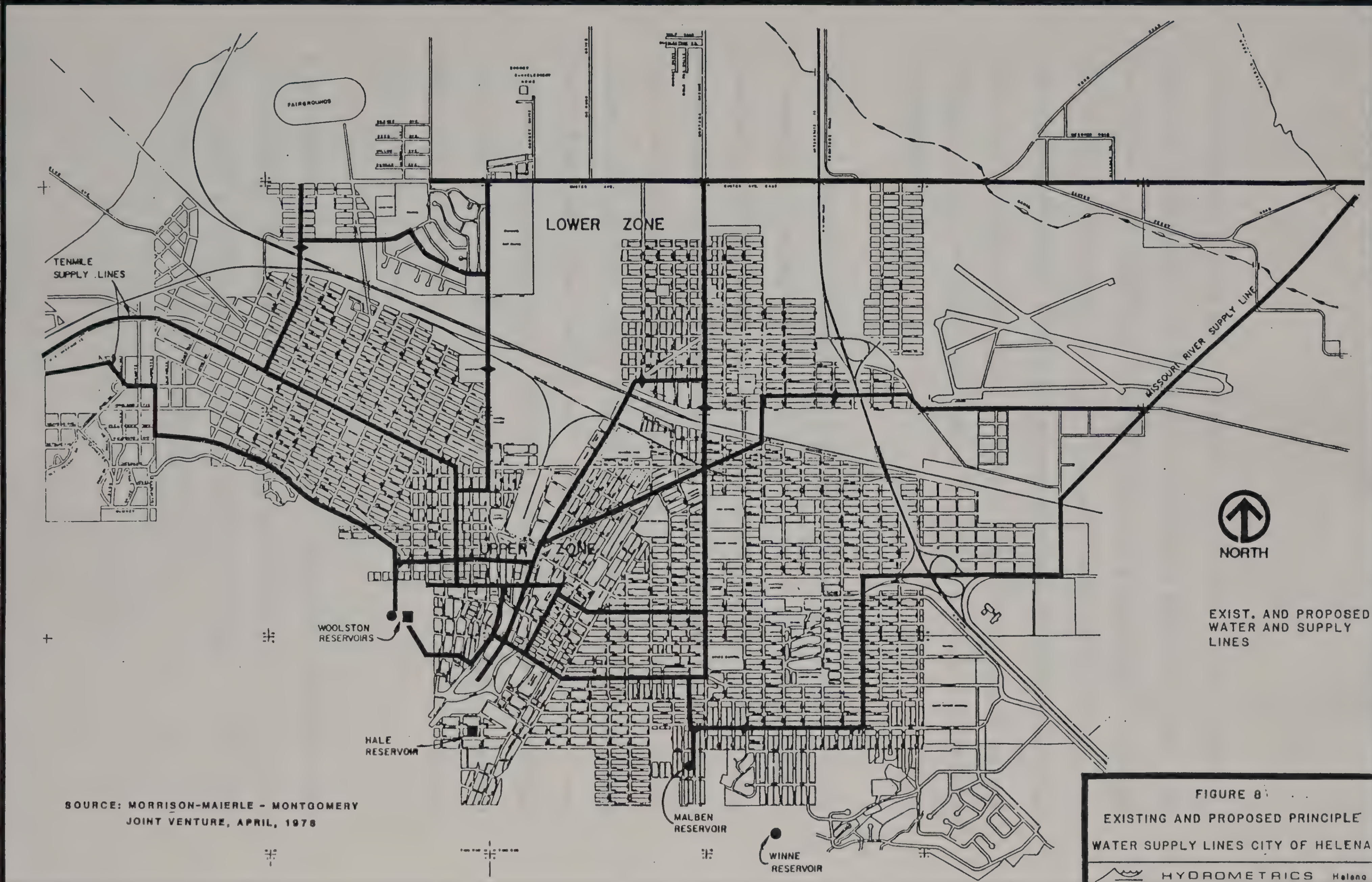


FIGURE 8

EXISTING AND PROPOSED PRINCIPLE WATER SUPPLY LINES CITY OF HELENA

as much as 450 gpm or possibly more. High capacity wells (Plate 1) extend to depths over 300 feet. In the eastern portion of this area near highway I-15 there are few wells and the groundwater development potential is essentially unknown. Sources of recharge in this area are infiltration from Last Chance Gulch, the municipal stormwater and water distribution system and other tributary drainages south of Helena. Irrigation in the north portion of the area also is a source of groundwater recharge.

Major groundwater development constraints in this area are the lack of a demonstrated potential for high capacity wells and the presence of numerous existing domestic, stock and public supply wells. Other constraints are the distance from existing city water transmission lines and the high pumping head required to supply the Woolston-Malben system. This area has some potential for furnishing in excess of 500 gpm to a properly constructed well, however considerable additional exploration is needed, particularly to investigate the existance of deep, high capacity aquifers. Based on the limited hydrogeological data the overall potential of this area to supply water for municipal purposes appears to be fair.

A groundwater development option for this area would include drilling of several conventional wells to form a well field. The well field would need a chlorination facility and would require piping and connection to the city distribution system.

BEDROCK AND TRIBUTARY VALLEYS SOUTH OF HELENA

This area includes drainages south of Helena including Last Chance Gulch and its tributaries Orofino, Grizzly and Dry Gulches and a few smaller drainages. This area consists primarily of sedimentary and igneous bedrock with unconsolidated alluvium along the main drainages. Groundwater recharge in this area primarily is from infiltration of precipitation and streamflow. Constraints to groundwater development in this area are:

1) The area already has been developed for groundwater by the Hale and Eureka Systems,
2) Alluvium in the area is thin, narrow and has a limited storage capability,
3) Recharge to the system is seasonal and would be unreliable for long-term, high capacity groundwater production.

Bedrock in the area contains water in fractures and joints that have a limited storage capability. Fracture zones would be difficult to locate and intersect by drilling. There are no deep wells in this area and the potential for deep groundwater has not been determined. There has been no evidence developed in this investigation or in previous hydrogeological investigations to indicate that bedrock south of Helena has a good potential to supply groundwater for municipal purposes. The existing Hale and Eureka groundwater developments tap a large portion of the available alluvial groundwater occurring in these drainages. Although there are undoubtedly some locations in this area that potentially could supply 500 gpm, finding such areas, constructing

wells and having these areas produce large quantities of groundwater on a long-term basis would be a very risky development option. Overall the potential for development of groundwater in the bedrock south of Helena for municipal supply purposes is poor. Similarly the volume of alluvium in drainages is not adequate to store and transmit sufficient water to provide additional municipal supply.

TEN MILE CREEK VALLEY

The Ten Mile Creek area includes the valley along Ten Mile Creek extending from Helena upstream to the City of Helena settling basins (Plate 1, Figure 1). This area contains unconsolidated alluvium along the main drainage and is underlain at relatively shallow depths by sedimentary and igneous bedrock. Unconsolidated alluvium in this area is derived from outwash deposits from Ten Mile Creek, Colorado Gulch and other tributary streams in the area. The area contains a few reported high capacity wells in Ten Mile Creek alluvium. Groundwater recharge to the area is from infiltration of precipitation and streamflow. Due to the lack of wells in the area, particularly high capacity and deep wells, hydrogeology of the area is not well understood. Based on the limited available data, constraints to groundwater development in the Ten Mile Valley are shallow bedrock, seasonal nature of recharge from surface water and limited groundwater storage in alluvium.

Due to a lack of hydrogeological data the potential for development of groundwater is poorly known. A major advantage of this area is that it

is at the upper end of the Ten Mile Creek pipeline and the City of Helena has an adjudicated first and second water right on Ten Mile Creek for 550 miners inches (about 6,200 gpm) and has large storage reservoirs.

Based on the available hydrogeological information the groundwater development option that appears most appropriate for this area is the use of a collector well to take advantage of the shallow groundwater table and the relatively thin deposits of unconsolidated alluvium. A collector system would induce infiltration from the stream and would remove groundwater from a large area. It is possible that the collector could be operated in conjunction with a groundwater recharge system utilizing Ten Mile Creek water. Such a system would utilize recharge basins or spreading grounds upgradient from the collector well. If these unconsolidated alluvium materials have good vertical permeability then a collector well system potentially could supply large quantities of groundwater on a sustained yield basis. The groundwater development would consist of a collector well or wells, recharge basins, chlorination system, pumps and a pipeline to the Ten Mile Creek water transmission line.

EAST VALLEY

The East Valley groundwater area extends from Highway I-15 and the Helena Airport eastward to the east and north study area boundary (Figure 7). This area contains unconsolidated alluvium derived from outwash from Prickly Pear Creek. These alluvial deposits are generally shallow and permeable and well yields up to 1300 gallons per minute are

reported for the area. The area contains numerous domestic and stock wells and a number of high capacity wells (Plate 1). This area has a demonstrated ability to supply large quantities of groundwater to wells. The potential for groundwater development using deep wells in this area is essentially unknown.

Constraints in development of groundwater in the East Valley area are existing groundwater users in the area and the high pumping head to the Woolston-Malben system and more importantly the long distance from this area to water transmission lines with available transmission capacity.

A well development option for this area would be a well field consisting of several conventionally drilled wells connected to common pipe and electrical lines. This system would also require a chlorination facility and connection to the Helena water transmission or distribution system. The major constraint of this area is the cost of the transmission line and the pumping cost.

NORTH VALLEY

The North Valley groundwater area extends north of the study area boundary and includes the lower segments of Ten Mile and Prickly Pear Creeks. This area contains unconsolidated alluvium that is at least 100 feet deep, has a shallow water table and contains some domestic, stock, irrigation and domestic wells. Little well inventory work was done in this area but the area contains numerous high capacity wells

that produce in excess of 1000 gpm. Little is known of deep groundwater resources in this area.

Groundwater recharge in this area is from infiltration from streams and irrigation water from extensive irrigation in this part of the valley. The major constraints on groundwater development in this area are the long distance to water transmission lines and the differential in hydraulic head (about 700 feet) between the valley and the city.

GROUNDWATER DEVELOPMENT COSTS

An accurate cost estimate for groundwater development cannot be made until specific sites and development options are selected and hydraulic conditions are known. Preliminary cost of wells, pumps and transmission lines can be made by making reasonable assumptions about the system. To provide some elementary basis for determining potential groundwater development costs, the cost of wells, pumps and pipelines and associated facilities is estimated. Cost are as follows:

1) Collector Well — $500,000
   Assumes 4 MGD (2800 gpm) and 100 foot depth and building, chlorination and associated facilities.

2) Conventional Drilled Well — $100,000
   Assumes 1.4 MGD; 150 foot depth and building, chlorination and associated facilities. Also

includes a 300 HP pump to produce
about 300 psi.

3)	Pumping Costs per 1000 GPM (1.4 MGD): Assumes continuous pumping, 60 and 600 feet of total head and MPC 1983 General Rate Schedule.	\$ 8,000/year (low head) \$ 40,000/year (high head)
4)	Pipeline per 100 Feet: Assumes 12 inch diameter; high pressure normal burial.	\$ 3,500
5)	Maintenance per well installation: Includes building, well, pump, chlorination, pipeline and values.	\$ 4,000/year

These costs could vary considerably depending on the specific installation but these costs are useful for planning purposes.

A detailed comparison would involve calculation of capital and annual costs on present worth (Equivalent Initial Cost) basis and an equivalent annual cost basis for the useful life of the facility. Projected power rates, interest rates and other common cost factors must be the same for both water options to insure a valid cost comparison.

GROUNDWATER DEVELOPMENT RECOMMENDATIONS

Evaluation of hydrogeological information for the study area results in the following development recommendations:

WEST VALLEY

Two factors must be evaluated to determine the groundwater potential of this area. First, a detailed cost comparison must be made to determine if groundwater would be an economic alternative when compared to the Ten Mile Water Treatment Plant. The pumping head to put water into the Woolston-Malben system is a major operational cost consideration. For cost comparison purposes an adequate supply of groundwater can be assumed to be present. If groundwater can be developed at an acceptable cost, the next consideration is groundwater availability. Hydrogeological conditions in this area must be further evaluated and a minimum of two test wells are recommended. This will determine the potential for use of conventional or collector well systems in the area.

CENTRAL VALLEY

This area does not have a demonstated potential for supplying 9 to 15 MGD from shallow groundwater. Additionally, the area contains a large number of existing domestic, stock, irrigation and public supply wells. The potential for deep groundwater in this area is unknown but would be of interest. Deep groundwater possibly would minimize conflicts with existing groundwater users. Before consideration of testing for deep

groundwater, the cost of groundwater development should be determined and compared to the Ten Mile Creek Treatment Plant. The Central Valley area appears to have only a fair potential for groundwater development and has maximum conflict with existing appropriators. No additional work is recommended for this area.

BEDROCK AND TRIBUTARIES SOUTH OF HELENA

There are few deep wells in bedrock; however, this area has not been demonstrated to be capable of supplying adequate water for municipal purposes. General hydrogeological considerations suggest that bedrock would have a poor potential for supplying adequate water for municipal purposes. Alluvium in the area is already developed for municipal supply and the potential for additional development of large quantities of groundwater probably is not good. No additional work is recommended for this area.

TEN MILE CREEK

Groundwater development in this area would be advantageous because of the elevation, the presence of water transmission lines and the water rights position of the City of Helena. Groundwater conditions are poorly known and there are few existing wells. It is recommended the area, particularly the upstream portion, be further investigated and a minimum of two test wells drilled to determine groundwater conditions. The potential for use of conventional or collector wells should be determined.

EAST VALLEY

The East Valley area has the demonstrated capability of supplying large quantities of groundwater and probably could supply the 9 to 15 MGD required for municipal purposes. The major problem in this area is the distance to a water transmission line and the difference in elevation (about 600 feet) between the potential well sites and the upper pressure zones in the city. It is recommended that a cost comparison be made between a groundwater supply and the Ten Mile Creek Water Treatment Plant. If costs are comparable, then selection of sites and drilling of a minimum of two test wells is recommended.

NORTH VALLEY

Hydrogeological conditions in the North Valley are similar to those in the East Valley area. Groundwater is abundant in the North Valley and conflicts with existing groundwater users would be small. The major constraint in this area is distance to water transmission lines and the difference in hydraulic head between the valley and the city (about 650 feet). Well development options would essentially be the same as for the East Valley; that is, a cost comparison must be made with the Ten Mile Creek Water Treatment Plant. If costs are acceptable, then specific drilling sites must be selected and test wells drilled. No additional work is recommended for the North Valley at this time.

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APPENDIX A

ABBREVIATIONS

ABBREVIATIONS

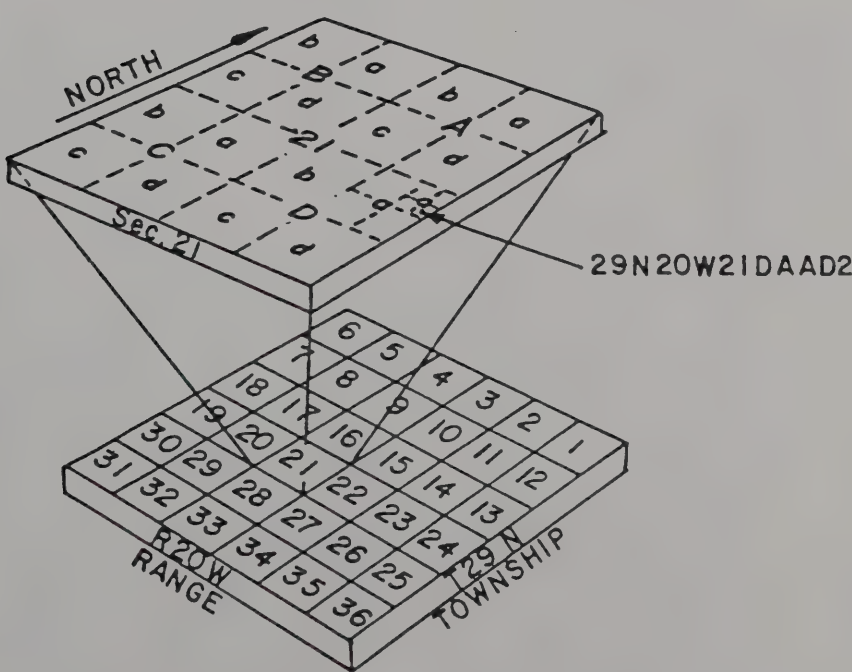
cfs	cubic feet per second
DNRC	Department of Natural Resources and Conservation
gpd/ft	gallons per day per foot
gpm	gallons per minute
MBMG	Montana Bureau of Mines and Geology
MGD	million gallons per day
T	transmissivity

APPENDIX B

SYSTEM FOR GEOGRAPHICAL LOCATION OF FEATURES

SYSTEM FOR GEOGRAPHICAL LOCATION OF FEATURES

Geographic features such as sampling sites, wells and springs are assigned a location number based on the system of land subdivision used by the U. S. Bureau of Land Management. The number consists of 10 to 16 characters and describes the location by township, range, section and position within the section. The figure below illustrates this numbering method. The first three or four characters of the number give the township, the next three or four the range. The next two numbers give the section number within the township and the next letters describe the location within the quarter section (160-acre tract) and quarter-quarter section (40-acre tract). If the location is known to sufficient accuracy then one or two additional letters can be used to describe the quarter-quarter-quarter-quarter section (2 1/2-acre tract). These subdivisions of the 640-acre section are designated as A, B, C and D in a counterclockwise direction beginning in the northeast quadrant. If there is more than one feature in a tract, consecutive digits beginning with the number 1 are added to the number. For example, if a sampling site was in Section 21, Township 29 North, Range 20 West, it would be numbered 29N20W21DAAD2. The letters DAAD indicate the well is in the southeast 1/4 of the northeast 1/4 of the northeast 1/4 of the southeast 1/4 and the number 1 following the letters DAAD indicates there is more than one site location in this 2 1/2-acre tract. If geographic features are located to the nearest 40 acre or 10 acre tract, the numbering methodology is the same except the last one or two letters are absent.



APPENDIX C

RECORD OF CONTACTS
HELENA GROUNDWATER STUDY

RECORD OF CONTACTS
HELENA GROUNDWATER STUDY

Contact/Organization	Date	Subject	Location
T. Allen	4-27-83	Beaverhead subdivision supply - 2 wells for test data available	10N03W17BA
N. Alm	5-9-83	Two irrigation and stock wells	10N04W28CC
D. Anders	4-29-83	Trailer Court Supply, two wells	10N03W18AD
J. Anderson	4-28-83	Irrigation wells and Crystal Springs, two 450 gpm wells	10N04W13DA
D. Armstrong	4-28-83	Private wells	10N04W23BB
J. Armstrong Mt. Dept. Highways	4-27-83	Highway Dept. drilling and information on area groundwater	Study Area
A. Austin	6-1-83	Slaughter House Wells	10N03W26AA
L. Balls DHES Water Quality Bureau	4-26-83	Prickly Pear Creek Study	Study Area
T. Berry Morrison-Maierle	4-21-83	City water supply system Piping and future demands	Study Area
A. Brandon Lewis & Clark County Fairgrounds	5-13-83	Woolston well test	10N04W13CC
H. Brandt	5-11-83	Domestic well	10N04W23AA
D. Burnham	4-27-83	Gravel pits and irrigation	10N03W15DB
S. Buswell	4-28-83	Irrigation wells and Ten Mile Creek flows	10N04W23BB
B. Carlson	4-28-83	Domestic and irrigation wells, conduct well test	10N04W14DD
T. Carson	5-2-83	Irrigation well - not found	10N04W23AA

J. Clausen Clausen Distributing	5-2-83	Former Kessler Brewery water supply	10N24W23
C. Clawson Archie Bray Foundation	4-28-83	Domestic wells	10N04W23BB
W. Cottrill	4-28-83	Irrigation well for sod farm	10N03W14AC
W. Criswell Former Engineer Porter Bros. Dredge	4-27-83	Water encountered in dredging activities	10N03W18
C. Dickert City of Helena Water M&O	3-24-83	City of Helena water system and Ten Mile wells	Study Area
W. Diehl	4-27-83	Well at Bull Run - no pumping information	Study Area
P. Drennon	4-28-83	Old Green Meadow Ranch wells	10N04W13
R. Dunn Veterans Admin. Engineering	4-26-83 5-13-83	Test wells at Fort Harrison Montgomery Engineering (1977) report	10N04W15
J. Eller Green Meadow CC	3-24-83	Golf Course water system and water rights	10N04W23
J. Elliott XL-Industries	4-28-83	Water supply well for old brickyards	10N04W23BB
B. George	4-25-83	Bedrock and Listner Spring System	10N04W36
J. George	5-2-83	Former Kessler Brewery wells	10N04W23
W. Glasscock	4-28-83	Domestic wells - Prickly Pear Creek	10N03W15
R. Gregor	4-28-83	Private well	10N04W22AC
F. Gruber	5-9-83	Hot water well for Broadwater Athletic Club	10N04W28AC
B. Gustine Mt. National Guard	5-4-83	National Guard Armory Conduct well test	10N04W30

W. Harrer	4-30-83	Wells, water rights and groundwater associated with old Green Meadow Ranch	Study Area
A. Hermanson	4-28-83	Irrigation well - 600 gpm	10N03W14DB
A. Herrin	5-31-83	Well 1100 gpm Well 500 gpm	10N03W11DC
G. Hiltabrand	4-28-83	Irrigation well, 100 gpm	10N04W14BC
D. Hoff Resurrection Cemetary	4-29-83	Irrigation wells for cemetary	10N03W17BC
D. Holland Laborers AGC Training Camp	4-28-83	Wells and shallow groundwater	10N04W14DD
D. Hurni	5-3-83	Well and bedrock system Last Chance Gulch	10N04W36DB
R. Issac	5-4-83	Irrigation well Ten Mile Creek at Colorado Gulch	10N04W31CC
M. Kaczmarek Morrison-Maierle	4-21-83	Helena area groundwater study and well tests	Study area
R. King	5-16-83	High yield well formerly Yuhas-Irrigation	10N04W18AC
K. Larson Former-City of Helena Water Department	4-27-83	City water system and groundwater	Study Area
Lewis & Clark County	4-26-83	Review water rights and exploration drilling files	Study Area
B. Lichtwardt	4-28-83	Irrigation well - 500 gpm	10N03W215BB
Warren Lindeke Layne-Minnesota Co.	4-22-83	Resistivity survey and test well reports for City of Helena	Study Area
T. Lindsay Lindsay Drilling Co.	5-24-83	Areas suitable for high capacity wells and tour of valley	Study Area
L. Maphies (Leisure Village Manager)	5-31-83	3 wells 500-1000 gpm Leisure Village	10N03W11DB
W. Miller	5-4-83	Domestic wells	10N04W28

B. Mills State Nursery	5-4-83	State Nursery well system	10N04W27
O. Mix Helena High School	4-26-83	Sump pumps in school service tunnels	10N04W22AB
Montana Oil and Gas Commission	4-26-83	Information on well logs in Helena vicinity - none	Study Area
J. Moreland USGS	4-19-83	Review Helena area ground-water information and USGS test data	Study Area
D. Munson	4-29-83	Unused irrigation well	10N03W15BA
E. Murgel City of East Helena	5-11-83	East Helena water supply well - test conducted	10N03W24DD
E. Nurse Foundation Materials	4-26-83	Water information from test drilling - Helena area	Study Area
J. Oitzinger	4-28-83	Irrigation well - 1040 gpm	10N03W15AC
A. Patterson	4-28-83	Domestic & stock well - 90 gpm	10N03W14ACD
R. Petrill Green Meadow Country Club	4-28-83	Country Club wells and irrigation system, 450 gpm	10N04W14ACD
J. Pomasko Helena Sand and Gravel	4-27-83	Helena Sand and Gravel wells and water use	10N03W28
L. Reynolds	4-28-83	Trailer court wells	10N04W23DA
A. Rose	5-3-83	Listner Spring - old mine workings	10N04W36A
L. Schneider	5-11-83	Domestic well	10N04W23BA
R. Schofield Helena Valley Irrigation District	5-12-83 5-24-83	Irrigation and recharge from Irrigation District	Study Area
L. Scott Former City of Helena Water Department	5-3-83	City water system	Study Area
M. Sennett	5-25-83	Spring 450 gpm	10N04W14CC

F. Shatz	4-28-83	Irrigation wells and Ten Creek irrigation system	10N04W15
P. Singer	4-29-83	Irrigation well - 100 gpm at Home of Peace Cemetary	10N04W24AB
C. Smallwood	5-9-83	Irrigation/stock well - 150 gpm	10N04W28CC
A. Smith Ten Mile Water Commissioner	5-26-83	Water rights and water use in Ten Mile and Seven Mile Creeks	Study Area
C. Smithers	4-28-83	Irrigation well - 90 gpm	10N03W14BB
T. Wester Sharbono Const.	5-31-83	Wells - 1400 gpm 1100 gpm 250 gpm	10N03W8BC 10N03W8BC 10N03W8BC
J. Willson Tri-County D&D	5-2-83	Irrigation well near Ten Mile Creek	10N04W22DA
E.Yuhas	4-29-83	Private well and information on irrigation wells	10N03W18

APPENDIX D

GLOSSARY OF TECHNICAL TERMS

GLOSSARY OF TECHNICAL TERMS

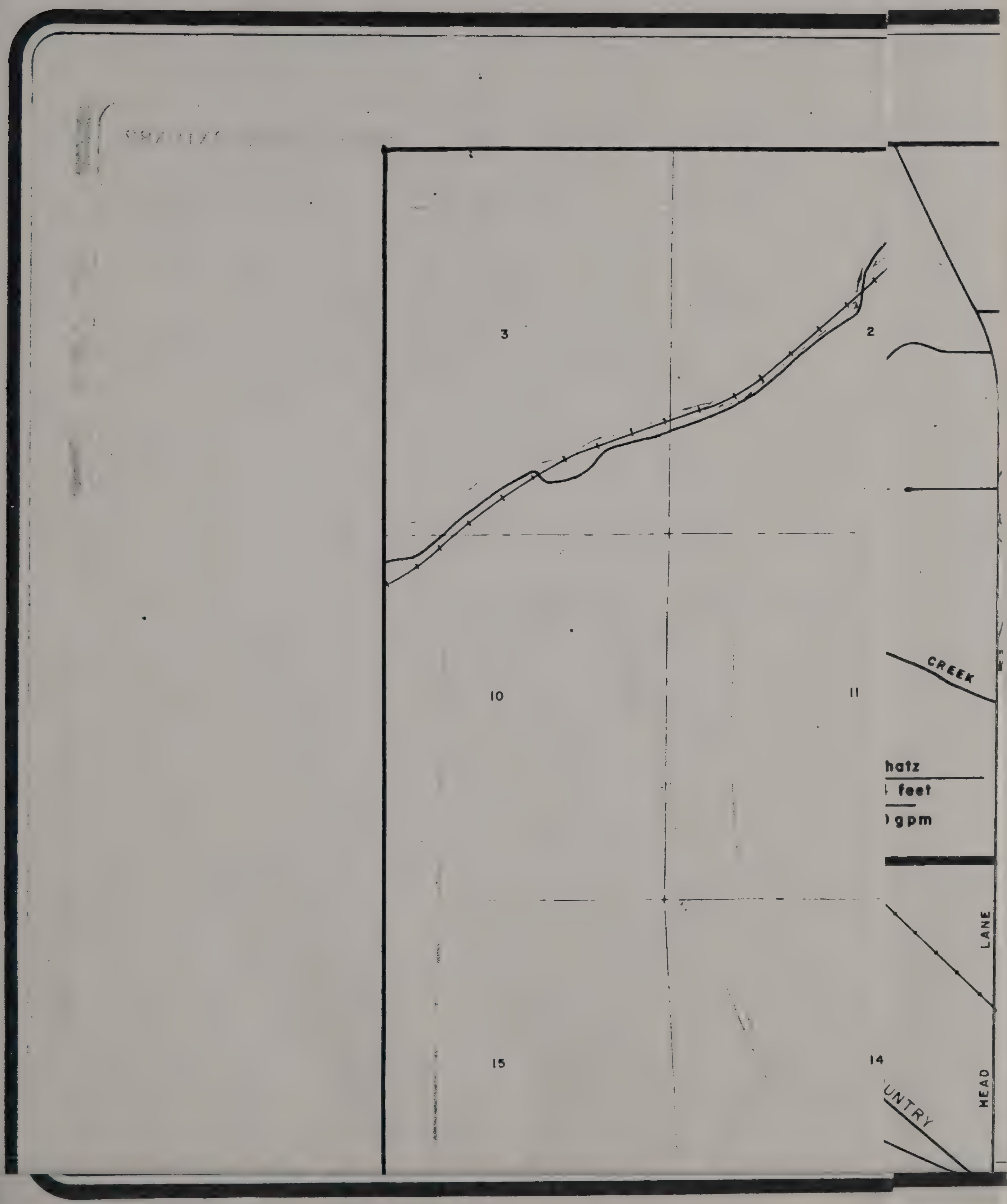
ALLUVIUM	A general term for stream laid deposits of comparatively recent origin; consisting primarily of clay, silt, sand and gravel.
AQUIFER	A geological formation containing saturated permeable material and capable of yielding significant quantities of water to wells or springs.
AQUIFER TEST	A test in which water is removed from (or added to) a well and the water level response is monitored to determine various hydraulic characteristics of an aquifer. Pumping tests where changes in water level and discharge rates are monitored are a common type of aquifer test.
ARTESIAN	Refers to groundwater that is under sufficient pressure to rise above the aquifer in which it is contained when tapped by a well. Artesian is synonymous with confined conditions. When the water level in an artesian well is above the ground surface the well is termed a flowing artesian well.

CONFINING LAYER	A layer or zone of relatively impermeable material lying above or below an aquifer of greater permeability. Confining layers typically consist predominately of silt and clayey materials.
HYDRAULIC GRADIENT	Pressure gradient; as applied to aquifers, it is the change in static head per unit of distance in a given direction. The slope of the water table surface in an unconfined aquifer generally defines the hydraulic gradient.
PERMEABILITY	Capacity of a material to transmit a fluid. Degree of permeability is a function of the size, shape and interconnection of pores in a geologic material.
POROSITY	The total volume of void space between grains or in joints and cracks in a geological formation.
QUATERNARY	A period of geologic time encompassing the period of recent glaciation up to the present. Generally considered to be the last million to several million years.

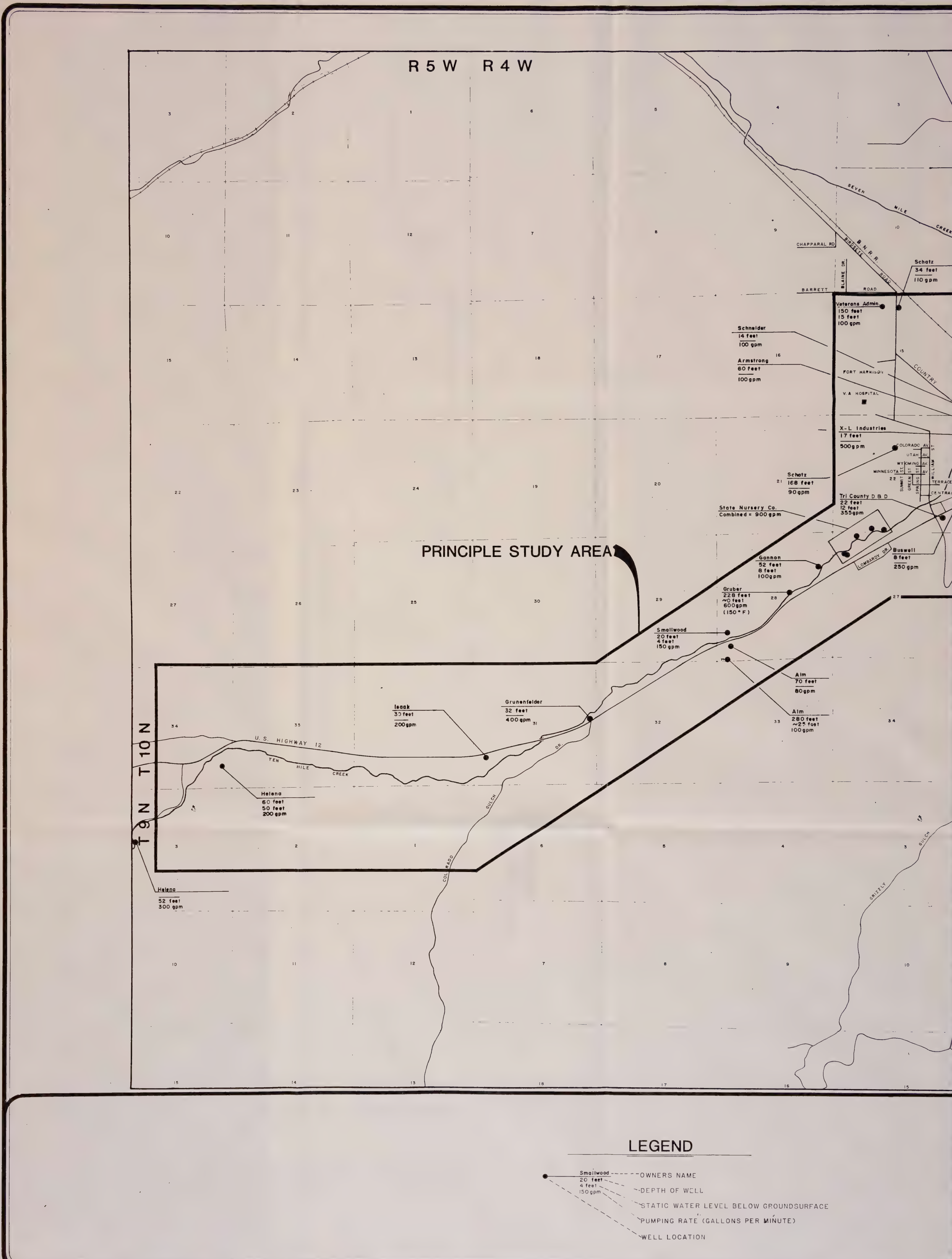
STORAGE COEFFICIENT	The volume of water that an aquifer releases from or takes into storage per unit surface area per unit change in head.
TERTIARY	A period of geologic time and referring to the geologic strata deposited during that time. Tertiary sediments in the Helena area are thought to range in age from approximately one million to twenty million years.
TRANSMISSIVITY	The rate of flow of groundwater under prevailing conditions in an aquifer of unit width under a unit hydraulic gradient. Common units for transmissivity are gallons per day per foot (gpd/ft) indicating flow across a slice of aquifer one foot wide under the assumed hydraulic gradient of one foot per foot. Greater values of transmissivity (T) indicate greater capability to transmit groundwater flow.
UNCONFINED	The condition where groundwater is exposed only to atmospheric pressure; synonymous with water table conditions. Shallow alluvial aquifers are generally unconfined.

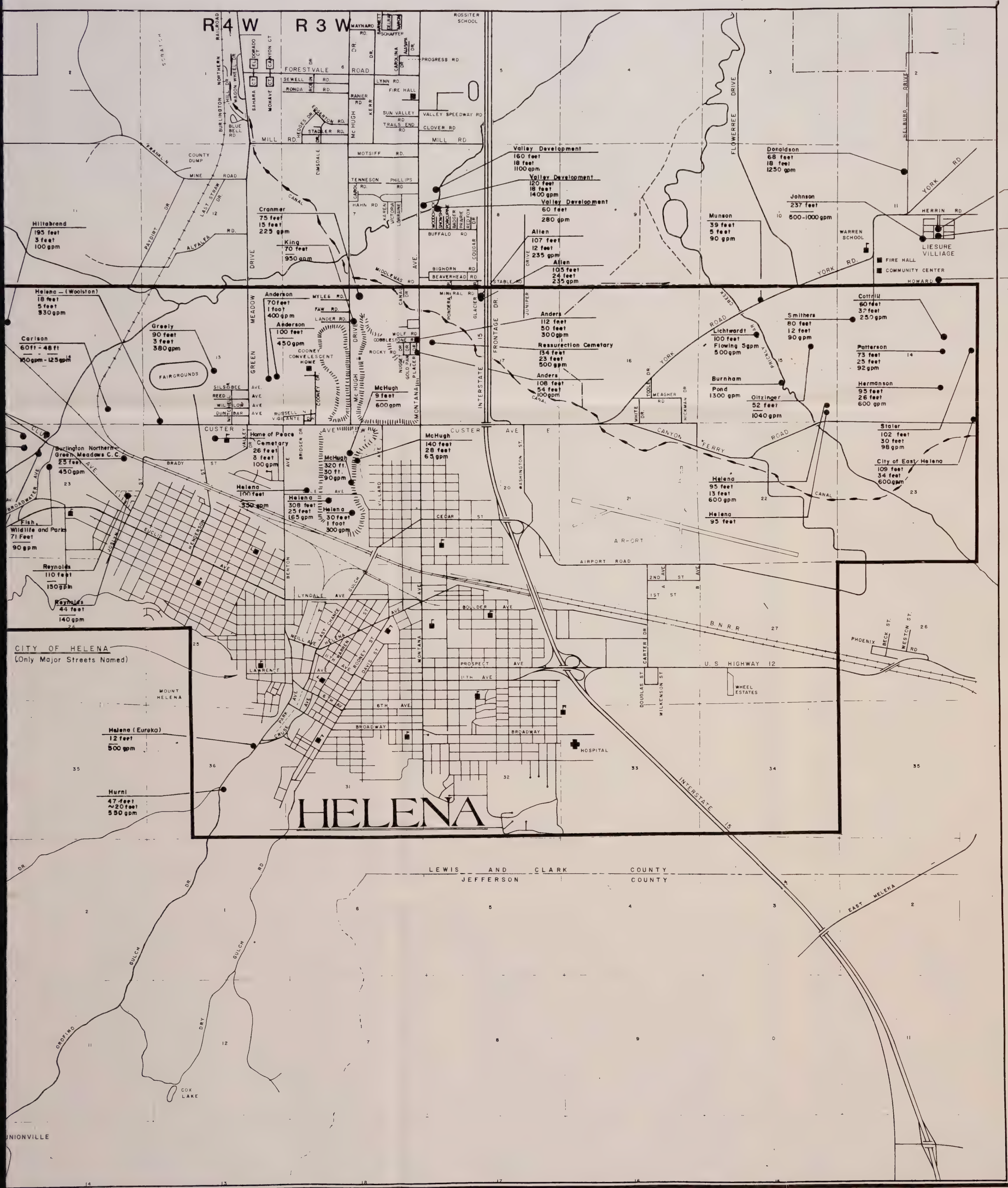
UNCONSOLIDATED — Indicating geologic materials that have not been hardened into solid rock by cementation, deep burial or high temperatures. Unconsolidated materials in the Helena Valley are generally alluvial sediments of Quaternary age consisting of clay, silt, sand and gravel.

WATER TABLE — The surface formed by the top of the saturated groundwater zone in an unconfined aquifer. A water table surface is under atmospheric pressure. Water levels in shallow wells generally define the water table surface.



3
2
10
11
15
14
CREEK
hatz
feet
gpm
LANE
HEAD
UNTRY


R 5 W R 4 W
T 10 N
T 9 N
PRINCIPLE STUDY AREA
SEVEN MILE CREEK
B.N.R.R.
BIRDSEYE ROAD
CHAPPARAL RD
BLAINE DR
BARRETT ROAD
COUNTRY
FORT HARRISON
V.A. HOSPITAL
COLORADO AV
UTAH AV
WYOMING AV
MINNESOTA ST
SUMMIT ST
GREEN ST
SPRING ST
WILLIAM ST
TERRACE
CENTRAL
LOMBARDY DR
U. S. HIGHWAY 12
TEN MILE CREEK
COLORADO GULCH
GRIZZLY GULCH
Schatz
34 feet
110 gpm
Veterans Admin.
150 feet
15 feet
100 gpm
Schneider
14 feet
100 gpm
Armstrong
60 feet
100 gpm
X-L Industries
17 feet
500 gpm
Schatz
168 feet
90 gpm
Tri County D.B.D.
22 feet
12 feet
355 gpm
State Nursery Co.
Combined = 900 gpm
Buswell
8 feet
250 gpm
Gannon
52 feet
8 feet
100 gpm
Gruber
228 feet
~0 feet
600 gpm
(150°F)
Smallwood
20 feet
4 feet
150 gpm
Alm
70 feet
80 gpm
Alm
280 feet
~25 feet
100 gpm
Grunenfelder
32 feet
400 gpm
Isaak
33 feet
200 gpm
Helena
60 feet
50 feet
200 gpm
Helena
52 feet
300 gpm
LEGEND
Smallwood — OWNERS NAME
20 feet — DEPTH OF WELL
4 feet — STATIC WATER LEVEL BELOW GROUNDSURFACE
150 gpm — PUMPING RATE (GALLONS PER MINUTE)
WELL LOCATION



SCALE

1 mile 1/2 0 1 mile

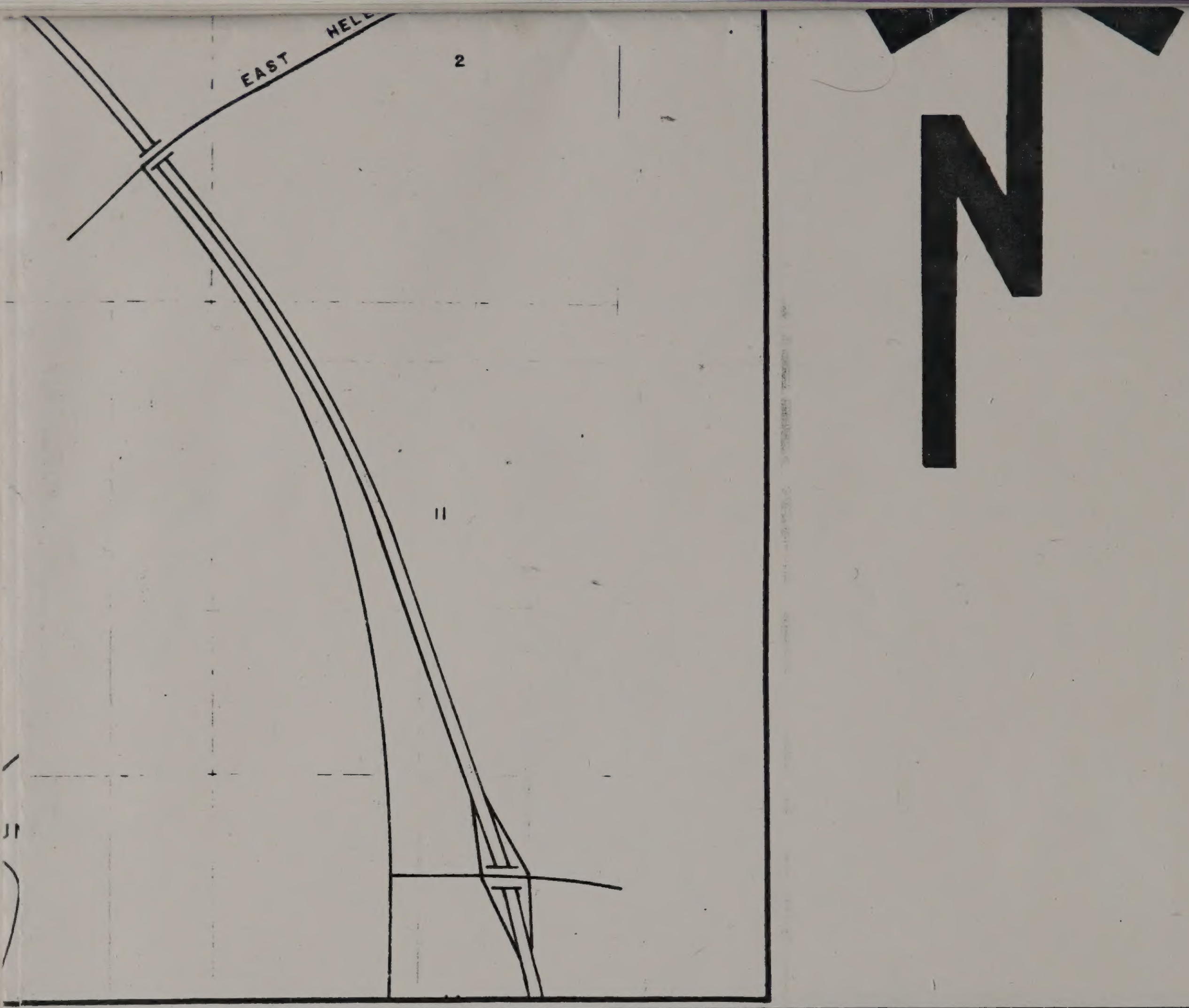
1000 Feet 0 2000' 5000 Feet

PREPARED FOR: CITY OF HELENA, MONTANA

LOCATION MAP OF HIGH CAPACITY WELLS IN THE VICINITY OF HELENA, MONTANA

PREPARED BY:
HYDROMETRICS

DRAWN BY: J.H.D. DATE DRAWN: 5/10/83



CITY OF HELENA, MONTANA

ION MAP OF HIGH CAPACITY WELLS
HE VICINITY OF HELENA, MONTANA

ETRICS DRAWN BY: J.H.D. DATE DRAWN: 5/10/83